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EARLY FRACTURE CALLUS IN NORMAL AND CORTISONE TREATED RATS

A Study by a Combination of Tetracycline Labelling, Microangiography and Microradiography

By

ANDERS HULTH and SVEN OLERUD

The healing process in experimental fractures has been the subject of comprehensive studies by various methods. The most important histological investigations in the last twenty years were those by *McLean & Urist* (13), *Pritchard & Ruzicka* (17) and *Ham & Harris* (7). These investigators showed primarily the dominant role of the periosteum in healing. Osteogenic cells in the deep layers of the periosteum proliferate and are differentiated into osteoblasts and bone salts are precipitated. The periosteal proliferation begins at some distance from the fracture line and then continues via the periosteum, which is raised from the corticalis, in towards the fracture line, forming a periosteal cuff. Callus is also formed from the endosteum. On a level with the fracture line, where the blood supply is poorer, cartilage is often formed instead of bone. The actual ends of the fracture are dead, the osteocytes there do not stain and even if they were alive, they could not take part in the osteogenesis, as they are enclosed in lacunae. It is an open question as to what extent undifferentiated cells from the bone marrow, the Haversian canals and the surrounding muscular tissue actively participate in osteogenesis. The precipitation of bone salts in the proliferation zone of the periosteum takes place at an early stage and can already be observed on a microradiogram on the fourth day (16). *Tonna & Cronkite* (21) investigated the cellular response with tritiated thymidine. They found that the cell proliferation took place mainly in the osteogenic layers of the periosteum but also in the mesenchymal

cells of the surrounding soft parts and that maximum proliferative response occurred 32 hours after the fracture.

Several authors have carried out microangiographic investigations on experimental fracture callus. *Lexer* and later *Koloday* found that local hyperaemia arises as the fracture heals. *Teneff* (20) found that the blood vessels derived mainly from the bone ends and from the pericallous soft tissue. *Ladanyi & Hidvegi* (12) found that the most important vascularization came from the marrow cavity, whilst the periosteal vascularization was less pronounced. *Wray & Lynch* (25) made plastic casts of the blood vessels from the extremities of the rat and compared the number of vessels in the fractured and the uninjured legs after the soft parts had been removed with potassium hydroxide. There was a substantial increase in vascular response from the third day onwards, with the largest peak on the ninth day. *Gothman* (6) investigated by microangiography the blood vessels in operative fractures of the tibia in rabbits and monkeys and found as a constant feature that it was primarily the vessels in the soft parts round the fracture that proliferated as bundles in towards the fracture haematoma. *Rhinelander et al.* (18) investigated by microangiography undisplaced closed fractures of the radius and ulna in adult mongrel dogs from one day to eight weeks after the fracture. They found that the medullary vessels were of greater importance than the periosteal in this type of fracture. The effect of cortisone on fracture healing was studied by *K. Kowalewski* (11), who found in humerus fractures in rats that the uptake of S^{35} was considerably less than in normal fractures. *Storey* (9) in a histological investigation of tibia fractures in rats found that cortisone produced so called dense callus. Cortisone does not prevent early callus but causes retarded resorption, leaving large amounts of cartilage callus. Bone of various degrees of maturity and non-union of the fracture were characteristic findings. *Duthie & Barker* (3) found that cartilage callus was rather calcified than ossified under the influence of cortisone.

The work reported here is an investigation using tetracycline induced fluorescence of proliferating bone tissue during fracture healing combined with indian ink microangiography on the same preparations. These preparations were in addition examined microradiographically. *Milch* (14, 15) found that in man and in experimental animals tetracycline localized itself in the newly formed bone and could be traced there with the aid of ultraviolet light, emitting a golden yellow fluorescence. Several investigations have since been made on tetracycline la-

belling principally by *Frost* (4 5) who has devoted a large number of papers especially to the conditions under which bone grows *Harris et al* (8) have recently published the results of a comparative investigation of labelling with different tetracyclines and autoradiography with Ca^{45} They found that the tetracyclines marked all the points of active bone formation The lacunae were also marked *Vanderhoeft et al* (24) carried out an investigation of tetracycline marking of the Haversian systems and studied their growth with repeated doses of tetracycline They also made comparisons between tetracycline localization and the degree of mineralization using microradiography

MATERIAL AND METHODS

Fractures of the tibia (left leg) were caused in 50 adult white weighing 200 g by breaking by hand The fracture was displaced *ad libitum* this was considered more suitable than altering the local experimental conditions by an operative intervention in the fracture region Cortisone was administered to half the rats 5 mg of Cortidrin® (Astra) per 100 g body weight was given intramuscularly each day after the day of fracturing After various periods (3 7 10 14 and 17 days) five or six animals were taken from each group for examination Two days previously the animals had received Terramycin® (Pfizer) in a dose of 50 mg per kg body weight Under ether narcosis the abdominal aorta was exposed and a catheter inserted in it through which Indian ink diluted with physiological saline (NaCl 1 3) was injected by hand with an ordinary syringe, after the animal had died The injection was given instalments with pauses after each 1–2 ml in order to eliminate the risk of bursting blood vessels and capillaries The animals were stored in the deep freeze until the whole experimental series was ready The bodies were then thawed in 10 per cent formalin the lower legs were detached and skinned and subjected to further fixation in formalin for another 24 hours The remaining soft parts were left undisturbed The specimens were then dehydrated in alcohol Storage for 24 hours in unpolymerized methyl methacrylate preceded the final bedding in methyl methacrylate to which 5 per cent of butyl phtalate had been added After polymerization the block of plastic was sawn into slices 0 5 mm thick in the longitudinal direction of the lower leg The slices were photographed by ordinary X ray and selected sections were ground by hand to a thickness of 100 μ These sections were then examined by microradiography and afterwards mounted under coverslips in fluo

rescence free balsam (Permount) The mounted preparations were then studied in a fluorescence microscope fitted with an UV light source One or two animals in each group were used for histological examination Decalcification was carried out with formic acid the specimens were bedded in paraffin and the sections 10 μ thick were stained with haematoxylin eosin

RESULTS

With one or two isolated exceptions the fluorescence in our preparations was very good There was however a certain reduction of intensity in the case of the animals treated with cortisone The indian ink filling of the preparations was likewise complete with one or two isolated exceptions In describing the healing of these dislocated fractures it is possible and advantageous to distinguish three areas of regeneration viz the periosteal and the endosteal proliferation areas and the interfragmental area In the first two areas callus is formed in connection with vascular hyperplasia and in the third there is an ingrowth of mesenchyme from the soft parts surrounding the fracture bringing with it blood vessels for resorption of the fracture haematoma In what follows we shall therefore deal with each osteogenic field separately and explain the differences we found between normal healing and healing under the influence of cortisone

1 *The Periosteal Osteogenic Area*

As early as the first few days cell proliferation takes place in the deep layers of the periosteum (Fig 1) The maximum proliferation takes place at a certain distance from the actual end of the fracture and then gradually decreases along the injured leg within an area of varying size The normal vascular supply to periosteum and bone consists of longitudinal vessels outside the fibrous layer From these vessels small branches pass in often perpendicularly through the periosteum and through the corticalis The proliferation layer in the periosteum increases in width at a rapid pace the distance of the longitudinal vessels from the corticalis increases and the perpendicular vessels in the proliferation layer of the periosteum increase especially in length but also in thickness As early as the third day after the fracture there appears on microradiograms from both normal and cortisone fractures a growth of poorly mineralized osseous spiculae in the basal part of the periosteal proliferation zone These spiculae fluoresce very clearly

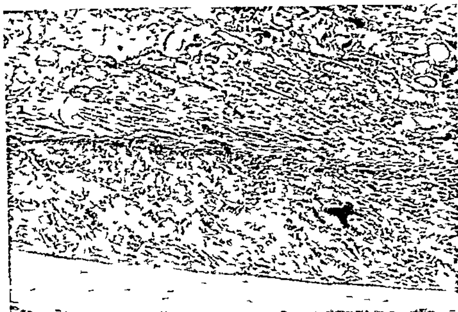


Fig 1

Micr photograph Periosteal callus on the fourth day At the bottom the corticalis above it the periosteal proliferation with newly formed trabeculae The periosteal zone is separated from the surrounding musculature by a fibrous layer Haema toxylin eosin Magnification × 30

with the Terramycin taken up (Figs 2 a and b) After a week the peri ostcal callus has increased considerably as regards both mineralization and vascular hypertrophy as is clear from the microradiograms and the fluorescence microscopy In Figs 3 a and b we see how the blood vessels penetrating the periosteum run in parallel through the callus and after having changed direction somewhat penetrate the corticalis and then empty themselves in the veins of the marrow cavity (Fig 3 b) We often see how the blood vessels penetrating the periosteum gather together as it were in the shape of a fan in the direction of the area of maximum proliferation (Fig 3 b) The direction of these transverse periosteal vessels seems to be independent of the progress of the vessel through the corticalis

In displaced fractures produced by the above method the periosteal injury will as a rule be greater on the convex side of the displacement than on the concave side On the former side the periosteum must necessarily be torn off whilst on the latter side there is some possibility of its holding together like a bridge between the ends of the fracture

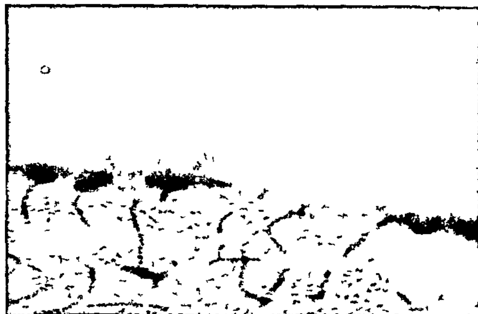


Fig 2 a

Microangiograph Callus three days old in a cortisone treated rat Bone trabeculae with a low degree of mineralization are visible outside the corticalis Thickness of section 100 μ Magnification × 50

On the more protected side the periosteum in spite of the fact that it has been released from the corticalis seems to form the regeneration centre for the callus which often has the form of a bridge between the fragments Several preparations show this state of affairs and there does not seem to be any difference in the principle of the bridge construction between normal rats and cortisone rats (Fig 4) This bridge building callus consists of trabeculated bone is practically always developed without an intermediate cartilage stage and is therefore reminiscent of the purely periosteal bone callus formation There are perhaps not sufficient periosteal vessels to supply this periosteal flap but it also seems to be possible to obtain a supply of blood through vessels newly formed from the environment and growing into the flap This state of affairs seems also to be proved by Fig 4 The superseded periosteum may therefore conceivably serve more or less as an autoplastic graft

The rats under cortisone medication develop a periosteal callus which is in principle completely identical with the callus in the normal rats However in the cortisone rats there are remarkably often an irregular

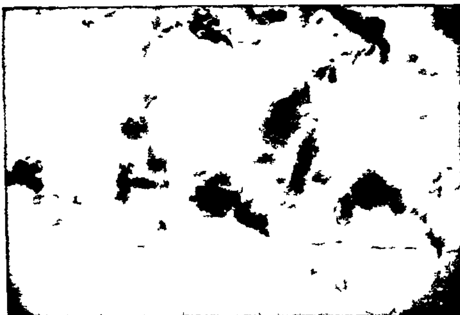


Fig 2 b

Microangiography + fluorescent microphotograph of the same spot as Fig 2 a The newly formed trabeculae fluoresce relatively distinctly Vessels filled with Indian ink pass perpendicularly through the callus Thickness 100 μ Magnification × 50

ity and an absence of trabecular structure together with avascular areas In respect of time there also seems to be a pronounced delay as regards callus development

2 *The Medullar Osteogenic Area*

Proliferation in the opening of one or both fragments is visible at the same early stage as proliferation in the periosteal zone The microangiograms reveal vascular hyperplasia stretching out towards the opening of the fragment in the form of a bundle Even on the third day a Terramycin fluorescence is observed round these vessels indicating incipient mineralization Callus is established here directly as trabecular bone without an intermediate cartilage stage On the seventh day after the fracture there is already a large callus which begins a few millimetres inside the opening of the fragment and grows up to it (Fig 3) The callus formation seems to be preceded by a vascular bundle pointing in the direction of the haematoma outside Medullar callus formation may occur in both the proximal and 1



Fig 3 a

Microangiography + fluorescent microphotograph of callus 7 days old in the immediate vicinity of the fracture site The vessels run at right angles through the strongly fluorescing callus towards the corticalis Section 100 µ Magnification × 50

fragment It is sometimes absent in the distal fragment probably owing to the fact that the vascularization there has been damaged The marrow callus seems to be strictly confined to the actual marrow cavity We never find this callus continuing outside the opening of the fragment into the interfragmental fracture zone We have the impression that the callus proliferation does not take place from the endosteum to any particular extent To judge from our figures it seems more likely that bone formation develops in immediate connection with the growing blood vessels

The entire marrow cavity in the upper fragment is always abundantly vascularized and seems to be so to an even greater extent than is the case in our formal preparations without fractures

The medullar callus formation seems to develop in the same way in both the normal fractures and the cortisone treated fractures The formation of perivascular bone trabeculae takes place equally rapidly and on the same scale in both the series



Fig. 3 b

Microangiography + fluorescent microphotograph of callus 14 days old at a distance from the fracture site. Here the vessels run obliquely through the callus directed towards the fracture site (to the right in the picture). After passing the callus they change direction penetrating the corticalis into the veins of the marrow canal. 100 μ. Magnification × 50

3. *The Interfragmental Area*

In a displaced fracture there is formed around and between the two fragments a haematoma in which small fragments of bone and also fragments of muscular and connective tissue are often to be found. In histological sections we find in this area on the second and third days after the fracture a cell proliferation which after a few more days has increased very rapidly in extent. In this mass of cells there arise in several places islands of cartilaginous tissue probably on account of the fact that the vascularization does not proceed in step with the cell proliferation (Figs. 6 a and b).

Microangiograms from the third day after the fracture show a vascular proliferation from the soft parts of the environment consisting mainly of musculature in towards the interfragmental fracture area. The blood vessels coming from the marrow cavity also turn in the direction of this interfragmental area. All these vessels are strictly di-



Fig 4

Microangiography + fluorescent microphotograph of periosteal bridging callus at the top. To the left periosteal callus is forming on the inferior side. The bridge is partly nourished by vessels coming from the interfragmental area. Normal fracture 18 days old. 100 µ. Magnification × 15

rected to the apparently empty area, i.e. the haematoma between the ends of the fracture. This phenomenon is particularly clear in cortisone preparations from the seventh day after the fracture (Fig. 7). The reason is probably that the haematoma is resorbed and transformed so much more slowly under cortisone medication.

A bone callus is developed in the cell proliferation which arises in the interfragmental area. In many places this transformation to bone takes place via cartilage tissue. In the mass of cells there arise islands of cartilage tissue which are calcified in their matrix. These islands of cartilage have no direct blood supply, but they are probably nourished by diffusion from surrounding vessels. The calcium deposited also probably obtains its tetracycline by a process of diffusion. The microangiograms demonstrate the existence of these mineralized islands of



Fig 5

Microangiographs + fluorescent microphotograph Marrow callus 8 days old of cortisone treated rat From the opened marrow cavity outgrowth of osseous callus preceded by a vascular fan To the left periosteal callus of poor trabecular structure 100 µ Magnification × 30

cartilage by their very strong tetracycline fluorescence The preparations likewise demonstrate the palisade shaped pattern of blood vessels surrounding the cartilage though not penetrating it In a comparison of these microangiograms with the corresponding microradiograms we find that the mineralization seems to be of a remarkably low grade in spite of the strong fluorescence in these areas (Fig 9) Here and there however vessels seem to break through the islands of cartilage and at these points the mineralized cartilage is transformed into a trabecular bone tissue though of irregular form (Fig 8)



Fig. 6 a

Microphotograph of interfragmental callus 8 days old. A large area of almost avascular cartilage is seen. Outside the cartilage an abundant vascular mesenchyme. Haematoxylin-eosin. Magnification × 50.

A comparison between normal fractures and the cortisone affected fractures reveals a considerable difference in callus formation in the interfragmental area. The mineralized cartilage tissue is considerably more widespread and more irregularly shaped in the cortisone affected fractures than in the normal fractures. The transformation of cartilage to bone takes place much more slowly and is more incomplete in the former. In the normal fractures, on the other hand, there is an often rapid development into trabecular bone. In many places this transformation seems to take place without an intermediate cartilage stage. In preparations from cortisone treated rats there occur areas that are relatively large and apparently empty of blood vessels. Blood vessels are certainly directed towards these areas but they seem to have difficulty in growing further in towards the cartilage area. There seems to be far reaching retardation of the whole healing process, particularly as regards the resorption of the haematoma.

Microradiographs of the healing of the fracture also show a great difference as regards the quantity of callus.



Fig 6 b

Microangiography + fluorescent microphotograph of an area similar to that in Fig 6 a Callus 7 days old of cortisone treated rat The cartilage is in the center perforated by vessels around which trabecular bone is being formed At the top vessels forming a "palisade" No fluorescence in the cartilage but the newly formed bone is strongly fluorescing 100 µ Magnification × 50

In several preparations non vital osseous tissue which appeared to be undergoing resorption was found in the fracture area In preparations from a week after the fractures there is found an abundance of parallel vessels directed towards apparently avascular bone fragments or parts of the corticalis (Fig 10) This phenomenon occurs both in the normal and the cortisone affected fractures In preparations from our normal animals 14 days after the fracture blood vessels reached the dead bone These vessels or their terminal capillaries applied themselves to the bone surfaces in a way similar to amoebae In the corresponding microradiograms there is revealed an incipient resorption of the bone corresponding to the site of the vascular phenomenon (Figs 11 a and b) Other preparations also showed vascular perforations through the bone substance Microradiograms with bone resorption were not found in the cortisone treated fractures nor was it possible

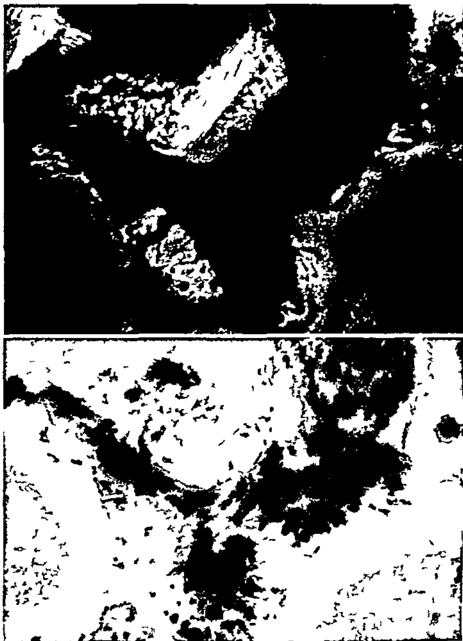


Fig 9

Microangiography + fluorescent microphotograph (9 a) compared with microradiography (9 b) of the same place in an interfragmental callus of a cortisone treated rat 17 days old There is mainly cartilage with calcification of low degree taking up abundant fluorescence Solely small areas of poorly trabecular bone To the right old fragments highly mineralized but not fluorescent 100 μ Magnification × 30



Fig. 10.
Microangiographs + fluorescent microphotograph. Probably avascular part of corticalis towards which newly formed vessels are directed. 100 µ. Magnification × 50.

this kind: two natural, i.e. operative during the growth period (the periosteal and the marrow area) and a third which arises owing to ingrowth of blood vessels from the surrounding musculature. The marrow zone is not necessarily made up of proliferation from the endosteum but may instead be a perivascular osteogenesis originating from the mesenchyme of the bone marrow. This marrow osteogenesis forms the so called sealing callus which seals the open marrow cavity. In delayed healing of a fracture this sealing of the marrow cavity seems to be an evil in that it prevents vascular contact between the marrow cavity and the interfragmental area and may thereby perhaps contri-

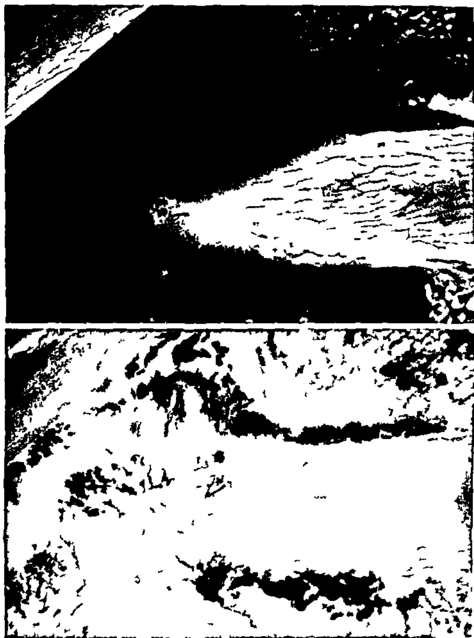


Fig 11

Microangiography + fluorescent microphotograph (11 a) compared with microradiography (11 b) of a necrotic bone fragment which is undergoing resorption by vessels applied to the bone surface. The microradiograph of the same spot shows incipient resorption. At the bottom fluorescent callus with a low degree of mineralization. 100 μ. Magnification × 30

bute to the genesis of a pseudoarthrosis We found a similar sealing of the marrow cavity with respect to the healing of amputation stumps in rabbits (9) That this callus can be formed directly from the blood vessels is to some extent confirmed by *Truetas* (22 23) finding that osteogenesis takes place owing to the conversion of vascular endothelial cells to osteogenic cells

The interfragmental osteogenic field arises through a substantial cell proliferation in the area of the fracture haematoma which is thereby transformed This transformation may take place owing to the ingrowth of blood vessels from the environment The blood vessels contribute to the resorption of the fracture haematoma and nourish the developed cell proliferation The vascular ingrowth directed towards the haematoma from the environment and from the marrow is probably due to some still unknown vessel stimulating factor (VSF) (*Trueta* (23)) This investigation cannot elucidate whether the actual proliferation derives from cells in the haematoma or from cells immigrating from the environment *Tonna & Cronkite* (21) found however on labelling tritiated thymidine that cell division also took place in the surrounding mesenchyme as well as in the periosteal field These authors do not seem to have investigated in detail the interfragmental area

The relatively substantial cortisone medication administered does not seem to have had any effect on callus formation within the marrow cavity In the periosteal callus zone on the other hand the cortisone seems to have retarded the course of development An irregularity and sometimes also avascular portions could be observed within the callus area The interfragmental callus formation was affected by the cortisone to an even greater extent The vascular proliferation in the direction of the haematoma seemed to be developed relatively quickly but in spite of this the haematoma did not seem to be resorbed in the normal way i e largely disappearing in the course of a week This was the case in all normal fractures In the animals that received cortisone large areas were found consisting of poorly mineralized but strongly fluorescent cartilage tissue without any real tendency to conversion into trabecular bone callus In the normal fractures osseous callus seemed to be largely developed directly from the osteogenic cells without a perceptible intermediate stage as cartilage The fractures in the normal animals were healed in the course of 20 days from both the clinical and the radiographical point of view This was not the case to any great extent with the cortisone treated animals Cortisone seems therefore to impede the specific osteogenic properties in the ingrowing

mesenchyme possibly producing a defect in the collagen synthesis. The resorption of debris at the fracture site also seems to be reduced. Our findings respecting the noxious effects of cortisone on experimental callus are in good agreement with those of previous investigators (3, 19). By the method we used, the noxious effects of the cortisone could be localized to mainly two of the three proliferation areas, viz. primarily the intermediate and to a certain extent the periosteal. Probably this state of affairs is connected with the fact that the interfragmentary healing zone is that in which the callus is formed via a cartilage stage. It is thus in the differentiation of the cartilage proliferation tissue to osseous callus that cortisone mainly introduces its noxious effects.

Interfragmentary callus formation is probably very important in fracture healing, especially in displaced fractures. Such fractures as a rule involve great injury to the periosteum and the soft parts. Even if the fracture is reset, healing is for this reason dependent to no small extent on the potency of the ingrowing mesenchyme. This may perhaps explain why disturbance of fracture healing in man is much more common in fractures that arise through high energy direct trauma than in those that arise through indirect force (1, 10). The severe muscular and cutaneous injuries that then arise would seem to lead to the fracture environment losing its ability to mobilize potent mesenchyme for this intermediate callus formation. If, besides this, there is later a difficult surgical resecting of such a fracture, perhaps with large osteosynthesis applications, further injury may conceivably arise in both the remaining periosteum and the soft parts. As regards the marrow callus, this does not seem to move outside the open orifice of the medullar cavity in the fracture site, but is probably of great importance in the healing of non-dislocated or slightly dislocated fractures (18). The task of the marrow callus seems to be to seal the marrow cavity as quickly as possible rather than to take part in the re-uniting of the fracture ends, i.e. the healing of the fracture.

The above reasoning is based on an investigation of fractures in rats, but it seems improbable that the healing of fractures could take place in fundamentally different ways in animals and in man (except that the lower animal species, on account of their potent mesenchyme, heal their fractures so much more easily). An earlier author (6) found no difference in vascular proliferation in such different animal species as rabbit and monkey.

SUMMARY

Histologic microangiographic and combined tetracycline labelling and Indian ink microangiographic techniques were used to study the healing of fractured tibia in rats Half the animals received cortisone In a displaced fracture there are three different sources of repair viz the periosteal the marrow and the interfragmental areas In the periosteal the marrow and the interfragmental areas In the periosteal there occurs proliferation of the osteoblastic cell layer and hyperplasia of preexisting vessels In the marrow area it is probably a matter of perivascular osteogenesis (not endosteal proliferation) and the callus does not grow past the opening of the fragment The third field viz the interfragmental is of great importance for healing Numerous vessels grow from the surrounding soft tissues into the haematoma where very rapid cell proliferation is brought about Islands of cartilage arise nourished by diffusion from end capillaries surrounding them The cartilage is often poorly calcified but takes up plenty of fluorescing tetracycline especially in the cortisone treated animals The cartilage is ossified through ingrowth of vessels The most obvious difference between the normal and the cortisone treated fractures is the delayed reconstruction of the fracture haematoma in the latter

RESUME

Des moyens histologiques microangiographiques et une combinaison d etiquetage a la tétracycline et des techniques microangiographiques a l encre de Chine ont ete utilises pour etudier la soudure des fractures du tibia chez les rats De la cortisone a ete administree a la moitie des animaux Dans une fracture deplacee il existe trois sources de guerison a savoir le perioste la moelle et les surfaces interfragmentaires Il se forme dans le perioste une proliferation de la couche des cellules ostéoblastes et une hyperplasie des vaisseaux preexistants Dans la moelle il est probablement question d osteogenese perivasculaire (et non de proliferation endosteale) et le cal ne se developpe pas par dessus l ouverture du fragment Le troisieme champ c est a dire la surface interfragmentaire est d une grande importance pour la guerison De nombreux vaisseaux surgissent a partir des tissus mous environnants dans l hematome ou des cellules de proliferation sont rapidement amenées Des ilots cartilagineux apparaissent nourris par diffusion des capillaires les entourant Le cartilage est souvent pauvrement calcifie mais absorbe bien la tetracycline fluorescente specialement

chez les animaux traités par la cortisone Le cartilage est ossifié par la croissance des vaisseaux La différence la plus apparente entre les fractures normales et celles traitées par la cortisone est le retard de reconstitution de l'hematome de la fracture dans le dernier cas

ZUSAMMENFASSUNG

Histologische mikroangiographische und kombinierte Tetracyclin Tuschemikroangiographische Verfahren wurden verwendet und die Heilung von Tibiabrüchen bei Ratten zu studieren Die Hälfte der Tiere erhielt Cortison Bei einem verschobenen Bruch findet man drei verschiedene Quellen der Wiederherstellung nähmlich das periostale das Mark und das Gebiet zwischen den Bruchstücken Im periostalen Bereich entsteht eine Proliferation der osteoblastischen Zellschichte und eine Hyperplasie vorhandener Gefässe Im Markgebiete dreht es sich wahrscheinlich um perivaskuläre Osteogenese (nicht um endostale Proliferation) und der Kallus wächst nicht über die Bruchöffnung hinaus Das dritte Gebiet nähmlich das zwischen den Bruchenden ist von grosser Bedeutung für die Heilung Zahlreiche Gefässe wachsen von den umgebenden Weichteilen in das Hamatom wo eine rasche Zellvermehrung vor sich geht Inseln von Knorpel die mittels Diffusion von den sie umgebenden Endkappilaren ernährt werden entstehen Der Knorpel ist oft spärlich verkalkt nimmt aber reichlich fluoreszierendes Tetracyklin besonders bei den Cortison behandelten Tieren auf Der Knorpen wird durch das Hineinwachsen von Gefässen verknöchert Der Ausfallendste Unterschied zwischen den normalen und den Cortison behandelten Bruchen ist der verspätete Hämatomwiederaufbau bei den letzteren

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DISLOCATION OF THE HIP INDUCED BY INSULIN IN THE CHICK EMBRYO

By

HELGE T. SEMB

The mode of origin and the morphological development of congenital dislocation of the hip during embryonic life have been the objects of various theories and our knowledge of their aetiology is still unsatisfactory. At the present time it is fairly clear that the cause may be both genetic and due to an unfavourable environmental factor affecting the foetus during its early development (1).

The possibilities of studying the development of the various congenital deformities during embryonic life are very limited in the human. However, such possibilities are much better in some experimental animals, e.g. the chick, where it is easy to induce various skeletal anomalies by experimental teratogenesis and thus obtain experimental material during different foetal stages. The production of skeletal deformities by the injection of insulin into the egg of the chick was first described by *Landauer* 1945 (2). In a paper in 1952 *Duraiswami* (3) showed that various particular skeletal deformities could be induced in chicks by insulin injections at different periods of incubation, and he drew up a plan of the localization of skeletal deformities depending on the time of injection. In his material *Duraiswami* also demonstrated a dislocation of the hip in a chick which was injected with 6 IU insulin on the sixth day of incubation. No detailed description of the frequency and development of dislocation of the hip seems to have been given by *Duraiswami* or by any other author.

The aim of the present investigation was in the first place to find out the possibility of reproducing a dislocation of the hip similar to that described by *Duraiswami*. If this proved possible, a material from different stages of embryonic life could be obtained so that the sequence of morphological deformities could be followed.

MATERIAL AND METHODS

Eggs of the White Leghorn were used The material was divided into three series In the first series 1379 eggs were each injected with 6 IU or 0 25 mg crystalline insulin in physiological saline solution on the sixth day of incubation Two series were used as controls In the first of these 111 eggs were each injected with 0 05 ml sterile saline solution at the same time after incubation In the second 598 completely untreated eggs were incubated and examined The material is shown in Table 1

TABLE 1

Mortality among chick embryos at different times and number of survived chicks

	No	Died early		Died at the time of hatching		Hatched alive		Survived at least 1 week
		No	%	No	%	No	%	No
Insulin injected	1379	1106	80	222	16	51	4	29
Saline injected	111	32	29	66	59	13	12	13
Untreated	598	157	26	313	53	125	21	108

The larger pole of the egg where the air chamber is situated was sterilized by washing and a hole was made through the shell into the air chamber Using an ordinary tuberculin syringe and a fine needle 0 05 ml sterile insulin solution prepared as described by *Sevastikoglou* (4) and containing 6 IU crystalline insulin was injected into the allantois The hole in the shell was then sealed with sterile tinfoil and *incubation continued Before injection every egg was illuminated and* only those considered to have a living embryo were injected

During examination of the material both X ray films and alizarin staining as described by *Couch et al* (5) were used The latter method was chosen because of the possibilities of studying the calcified skeleton as a whole and thus mutual relationship of the various skeletal parts to each other In the X ray investigation a projection was first used with the specimen in the prone position and legs approximately 90 abducted Later the specimen was X rayed in the supine position with the legs only 30 abducted in an attempt to show up latent dislocations

To study possible changes in the hip region serial sections of the pelvis and hips were taken in ten randomly chosen insulin treated and ten random untreated foetuses which died at hatching The sections were stained with haematoxylin eosin



Fig 1

Alizarin stained pelvic secti ns of chicks dead at hatching the upper treated with insulin the lower untreated Note the general retardation with bent short and broad leg bones in the upper picture The hip joints are normal in b th sections.



Fig 2
Three weeks old insulin treated chick with a clinically suspect left sided dislocated hip Note the laterally rotated left leg giving no support

RESULTS

Of the 1379 insulin treated chick embryos 1106 (80%) died soon after the injection Of the remainder 222 (16%) survived until hatching but died then while only 51 (4%) hatched alive Of these 51 only 17 survived at least two weeks when the inorganic component of bone in the hip joint is high enough for the X ray films to be assessed with a high degree of certainty

All the specimens in the insulin treated series which survived as far as hatching were examined with both X rays and alizarin (Fig 1)

The insulin treated embryos which died at hatching did not show any definite dislocation On the other hand they showed a strikingly large number of general skeletal deformities with short broad and bent bones In addition were found quite a number of local deformities like club foot and some cases with anomalies of the beak and anophtalmos A certain general retardation was also noticed among the survivors but no manifest deformities Among these were found four three weeks old chicks with suspected unilateral dislocation (Fig 2) These chicks only



Fig 3
Two three weeks old chicks with left sided dislocation of the hip
The right hip is normal in both

bore weight on one leg when walking while the other leg showed an abnormal mobility of the hip was considerably rotated laterally and gave no support However X ray examination confirmed a dislocation in only two of them and these were definite dislocations of the left hip (Fig 3)

Of the control embryos treated with saline 32 (29%) died early while 66 (59%) died soon after or at the time of hatching Only 13 (12%) survived Of the survivors five were killed and examined after a week four after two weeks and four after three weeks All in this series were examined by X rays but only 41 were stained with alizarin There was no sign of dislocation of the hip in a single case Furthermore *inspection showed normal development for the age in all and no* signs of the above mentioned skeletal deformities could be observed either on X ray examination or following staining with alizarin

In the other control series there was a total of 598 completely untreated embryos Of these 157 (26%) died early in the incubation period and 313 (53%) just before or during hatching while 128 (21%) hatched alive Apart from those dying early all in this group were X rayed and studied by staining with alizarin (See Fig 1 lower *picture) No case of dislocation of the hip or more serious skeletal de*formities was encountered in this group

In the material which was examined histologically normal cartilaginous structure was found without signs of special changes in the skeleton or surrounding tissues in both the insulin treated and untreated foetuses In addition bone formation was normal and similar in both groups without any definite signs of retardation in those treated with insulin

DISCUSSION

The results show that the possibility of producing dislocations of the hip as discussed in the introduction does exist to some extent However the methods used for recording deformities have been found inadequate so that possible dislocations of the hip during different embryonic stages could not be shown Only X ray examination gave certain diagnostic information and this was only positive in chicks at least two weeks old where the calfication of the hip skeleton makes it possible to assess X ray films There were two such dislocations among the 17 chicks of at least two weeks of age and in two others there were clinical signs of dislocation invisible on X ray probably because of unsatisfactory projection and possibly because reposition occurred by manipulations during the X ray examination Even if the material is much too small to allow statistical conclusions the percentage occurrence of dislocation diagnosed by X rays or by clinical examination in this series can be considered to be as high as 11 8% and 23 5% respectively It is also impossible to exclude further possible dislocations in the larger part of the material which because of the badly calcified skeleton could not be diagnosed with the methods used

Two series served as control material The former was to show if the injury for the embryos at the time of injection and the increase of pressure in its environment could be of importance for the development of malformation The latter was to study the possible occurrence deformity in a normal untreated series The untreated and saline treated embryos showed no tendency to malformation generalized or localized to the hip

In addition the results indicate that insulin injection in chick embryos during the sixth day of incubation produces both generalized chondrodystrophic skeletal deformities and isolated deformities in the hip joint It is known (*Landauer Duraiswami Sevastikoglou* (1 2 6)) that chondrodystrophy is produced when insulin is injected during the fourth day of incubation On the other hand it is known that the biological development and differentiation of the embryo can differ widely from its chronological age (*Lillie* (7))

It can therefore be assumed that in these experiments insulin affected both embryos which in spite of their chronological age were in a much earlier stage of development when the generalized malformations were induced and also embryos whose biological development agreed well with their chronological age when dislocation of the hip occurred The latter chicks appeared otherwise to have developed normally

In addition one should note the extremely high mortality (80%) and low hatching ability (4%) among the insulin treated compared with the control groups (29% and 12% for the saline treated embryos and 26% and 21% for the untreated embryos)

The relatively high mortality in the control groups can partly be ascribed to the lower quality and hatching ability of the eggs in the winter when the experiments were being carried out This point has previously been made by *e g Hutt & Greenwood* (8) Some slight temperature variations in the incubator can also have contributed to the low hatching ability The difference in this respect between saline treated and untreated embryos is probably due to the injury induced in association with the injection

The lack of major pathological changes histologically does not quite agree with the findings of *Anderson et al* (9) who found some morphological but no histochemical abnormalities in the growth cartilage of insulindwarfed chicks In this investigation however only the hip cartilage from ten randomly chosen chicks was studied and it must be pointed out that it is unknown whether or not structural changes occur in the embryos in which dislocation of the hip is induced

SUMMARY

Experiments were made to try and produce congenital dislocation of the hip by injecting insulin into the eggs of incubating chicks A total of 1379 eggs were treated Of these only 17 could be assessed with the methods used They showed four clinically suspected dislocations of which two could be roentgenologically verified Apart from these a relatively high incidence of generalized skeletal deformities and a high mortality was found

As controls 111 eggs were treated with physiological saline and 598 incubated without any treatment No pathological changes of importance were found in the control series All the specimens were examined by X ray All the insulin treated and untreated embryos as well as almost one half of the saline treated embryos were examined by the alizarin method

Ten of each of the insulin treated and the untreated embryos were examined histologically but no differences in cartilaginous and bony structure could be shown between the insulin treated material and the normal

RESUME

Des experiences ont ete entreprises pour essayer de provoquer une dislocation congenitale de la hanche par injection d insuline dans les oeufs d incubation de poulets 1379 oeufs au total ont subi le traitement Parmi ceux ci 17 cas seulement ont pu etre constates par les methodes utilisees Il s agissait de quatre dislocations que l on a pu soupçonner cliniquement et dont deux ont ete verifiees radiologiquement A part ces cas on a constatet une frequence relativement elevee de deformites squelettiques generalisees et un taux de mortalité eleve

A titre de controle 111 oeufs ont ete traites par sel physiologique et 598 incubes sans aucun traitement Les modifications pathologiques trouvees dans les series de controle etaient insignifiantes Tous les specimens ont ete examinés aux rayons X Tous les embryons traites par l insuline ou non traites ainsi que la moitie environ des embryons traites au sel ont ete examines par la methode de l alizarine

10 des embryons traites par insuline et 10 embryons non traites ont eté examines histologiquement mais aucune difference dans la structure cartilagineuse et osseuse n a pu etre observee entre les embryons soumis au traitement et les embryons normaux

ZUSAMMENFASSUNG

Versuche wurden ausgefuhrt mit der Absicht angeborene Huftverrenkungen mittels Injektion von Insulin in die Eier ausbrutender Huhner zu erzeugen Eine Gesamtzahl von 1379 Eiern wurden behandelt Von diesen konnten nur 17 mit den verwendeten Methoden beurteilt werden Sie zeigten vier klinisch verdächtige Verrenkungen von denen zwei rontgenologisch bestatigt werden konnten Abgesehen von diesen wurde ein verhaltnismassig haufiges Vorkommen von allgemeinen Skelettverbildung und eine hohe Sterblichkeit gefunden

Zur Kontrolle wurden 111 Eier mit physiologischer Kochsalzlosung behandelt und 598 wurden ohne Behandlung ausgebrutet Keinerlei pathologische Veränderungen von Bedeutung wurden in den Kontrollversuchen gefunden Alle Praparate wurden röntgenologisch untersucht Alle Insulin behandelten und nichtbehandelten Embryos wie auch beinahe die Hälfte der mit Kochsalzlösung behandelten Embryonen wurden mittels der Alizarinmethode untersucht

Zehn der Insulin behandelten wie auch der nichtbehandelten Embryonen wurden histologisch untersucht aber keine Verschiedenheit

der Knorpel- oder Knochenstruktur zwischen dem Insulin behandelten und dem normalen Material konnte nachgewiesen werden.

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CONGENITAL SYNOSTOSIS IN THE CERVICAL SPINE

By

POUL A. GJØRUP and LONE GJØRUP

The first detailed account of this syndrome was given in 1912 by *Klippel & Feil* from Paris. Until 1940 a total of 133 cases had been published.

Among several signs in the pronounced cases of the syndrome the most important are the following: the short neck with very restricted movements, the so-called wing neck or pterygium colli and the low hairline at the back of the head.

The purpose of this paper has been to determine the frequency of the syndrome in the population of Copenhagen and the nature and frequency of the accompanying deformities. The material comprises 76 cases collected from the archives of all X-ray departments in Copenhagen. In the years 1951–60 25 new cases were diagnosed. An estimation based on these figures results in a total of approximately 200 cases in Copenhagen, i.e. 0.2 per thousand. Probably this is a minimum figure because several mild cases would not be diagnosed on account of the lack of clinical symptoms. In some of the patients the synostoses were found quite accidentally by an X-ray examination of the trachea.

Table 1 shows the localization of the synostoses in the cervical spine. A classification is made according to the number of synostoses: 44 patients with one synostosis (between the vertebral bodies), 19 patients with two to five synostoses and 13 patients in whom all the vertebral bodies in the cervical spine are fused together. However, it is to be noted that the atlas is not involved in six of the 13 pronounced cases and not in any of the milder cases.

In the mild cases the synostoses seldom continue down in the thoracic spine, in the pronounced cases nearly always (Table 1), even to the eighth thoracic vertebra. The frequency of the synostoses is highest in

the upper part of the cervical spine and decreases gradually downwards. It is a curious fact that a single synostosis between the third and fourth body seldom occurs but in the 19 cases with two to five synostoses this localization is the most frequent.

TABLE 1

Localization	Synostosis: Number — One 41 cases	Two-five 19 cases	Six or more 13 cases
1–2 cerv. vert.	0	0	7
2–3	13	13	13
3–4	3	16	13
4–5	7	13	13
5–6 "	7	8	13
6–7	4	7	13
7 cerv. and 1 dorsal vert.	1	2	11

TABLE 2

Other deformities	Number of synostoses — One 41 cases	Two-five 19 cases	Six or more 13 cases	Total
In the cervical spine	57 %	47 %	[illegible]7 %	58
In the rest of the spine	54 %	44 %	100 %	62
Scoliosis				71 %
Scoliosis in the cervical spine	31 %	47 %	38 %	36
Scoliosis in the rest of the spine	46 %	56 %	23	44 %
Cervical rib	11 %	11 %	31 %	14 %
Sprengel's deformity	9 %	11 %	31 %	16

Table 2 shows the frequency of the accompanying vertebral deformities expressed in percentages. The subdivision is the same as in Table 1. In the column to the right the entire material is presented.

In the cervical spine accompanying deformities—usually clefts in the arches—are found in roughly half of the cases, most frequently in the cases with six or more synostoses. In the rest of the spine other deformities—frequently synostoses—are seen in about half of the mild cases but in all the pronounced cases, pointing to the fact that the cervical

spine is not the only localization of the syndrome but should be considered as the topographical center of the syndrome—frequently the skull is involved too

Scoliosis is found in 71 per cent of the cases apparently more frequently in the mild cases and outside the cervical spine Cervical ribs and Sprengel s deformity are seen in 1/10 of the mild and 1/3 of the pronounced cases respectively

The cause of the deformities is unknown but apparently the disease might be hereditary For obvious reasons comparison could be made with Turner s syndrome patients with this syndrome sometimes are shortnecked and wingnecked just as patients with Klippel Feil syndrome sometimes show hormonal insufficiency

Finally it should be mentioned that recently it has been proved that X ray irradiation of pregnant mice results in various deformities in the foetuses especially in the cervical spine

SUMMARY

The material comprises 76 cases and it is estimated that the syndrome is found in 0 2 per thousand in the population of Copenhagen The synostoses are most frequently found in the upper part of the spine in 13 cases the cervical spine is *completely* synostosed Other vertebral deformities in the whole spine are found in about 50 per cent scoliosis in 71 per cent Sprengel s deformity in 16 per cent of the cases

RESUME

Le materiel d observation compte 76 cas et on calcule que le syndrome existe chez 0 2 p mille de la population de Copenhague Les synostoses sont observees le plus frequemment dans la partie superieure de la colonne vertebrale dans 13 cas la colonne cervicale etait complement synostosee D autres deformites vertebrales dans toute la colonne ont ete trouvees dans environ 50 % des cas la scoliose dans 71 % la deformite de Sprengel dans 16 % des cas

ZUSAMMENFASSUNG

Das Material umfasst 76 Fälle und man schätzt dass das Syndrom bei 0 2 per Tausend in der Bevolkerung von Kopenhagen zu finden ist Die Synostosen sind am haufigsten im oberen Teile der Wirbelsaule zu

funden. In 13 Fällen war die Halswirbelsäule vollständig synostosiert. Andere Missbildungen in der ganzen Wirbelsäule wurden in ungefähr 50 % gefunden. Skoliose in 71 %. Sprengels Missbildung in 16 % der Fälle.

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TRANSTHORACIC APPROACH FOR VERTEBRAL EPIPHYSEODESIS

By

ULF NILSONNE

The experiences of spinal fusion in the treatment of scoliosis have in our hands been rather discouraging On the average the progression of scoliosis in the more severe cases has been checked but only to a minor degree has it proved possible to improve a curve that has already been established (7) Since the results have proved uncertain and the time of treatment is long (approximately 1 year) this method has been reserved for the most severe cases and we have tried to find other methods for the operative treatment of scoliosis

A characteristic feature of a scoliotic curve is that the vertebrae are wedge shaped so that they are lower on the concave than on the convex side of the scoliosis (Figs 1 and 2) This means an increased load on the vertebral epiphyses on the concave side the growth of which is thus checked On the convex side on the other hand growth is relatively too fast which can further accentuate the development of the curve

Working on this basis a number of attempts have been made to produce scoliosis in animals by bringing about an asymmetric growth of vertebrae This has been done by blocking the vertebral epiphyses on one side with some form of staples or by the excision of the epiphyses over half the vertebrae In this way *Haas* (2) *Nachlas & Borden* (5) and others have produced scoliosis in dogs and *Pacher* (8) in pigs *Nachlas & Borden* (6) also succeeded in straightening out an experimentally induced scoliosis by destroying the growth centres on the convex side

This naturally suggested the possibility of influencing a human scoliosis by directing the growth of the vertebrae It is surprising however how few such attempts have been made This can partly be explained by the disagreement long prevalent as to what extent the

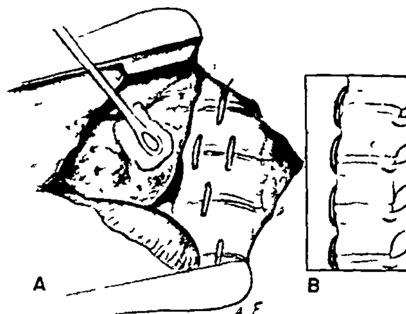


Fig 3
A method for stapling vertebral bodies (From *Smith von Lackum & Wylie*)

been pushed to one side one has a very good view of the scoliotic convexity and can easily put oneself in the picture as regards the topography of the vertebrae The dorsal pleura is divided an incision made in the periosteum and the vertebrae laid bare subperiosteally to half their extent on the convex side (Fig 4) The epiphyseal plate is then removed with a chisel to half the extent of the vertebra on the cranial and caudal sides of the vertebrae within 4–5 levels of the vertex of the scoliosis The intervertebral disc tissue is also removed to half the extent of the vertebrae (Fig 5) Afterwards careful staunching of blood is carried out the resection surfaces for instance are waxed Suture of periosteum and pleura and closure of thoracotomy in layers take place A drainage tube is routinely put in for 24 hours

Postoperative development has been entirely free from complications

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Figs 4 5

Fig 4 Transthoracic view of the vertex of the scoliosis The lung is pushed to the right side The periosteum is dissected from the vertebrae and discs which appear grey and white respectively in the picture

Fig 5 After excision of epiphyseal plate and disc within half the extent of the vertebrae



Fig 4



Fig 5



Fig. 6
The X-ray picture immediately after the operation

The patients have been allowed to get up on the 4th or 5th day after the operation without support in the form of a brace or similar aid. No back pains have been reported. After some 6 weeks patients were attending school in the normal way, although they did not take part in Physical Training.

That an epiphyseal plate really had been excised was clear from the histological picture in which the palisade arrangement of the cartilage cells could be seen. The picture taken at the operation showed that the local operation defect was quite extensive. The tissue removed (epiphyseal and disc tissue), however, absorbs roentgen radiation only to a minor extent, so that the operation defect appears as only very slight on the X-ray film (Fig. 6).

The object of this report is just to present a simplified technique for vertebral epiphyseodesis. Since the operation material is as yet rather small and the period of observation short, the clinical effect of the method will be presented when the series has been increased.

SUMMARY

The author describes a method for directed growth control in scoliosis. The operation consists of resection of the epiphyseal plates and the discs to half the extent of the vertebrae on the convex side of the scoliosis. The operation is performed by a transthoracic approach.

RESUME

L'auteur decrit une methode de controle de croissance dirigee dans la scoliose. L'operation consiste en une resection des plaques epiphysaires et des disques dans la moitie de l'etendue des vertebres du cote convexe de la scoliose. L'operation est accomplie par approche transthoracique.

ZUSAMMENFASSUNG

Der Verfasser beschreibt eine Methode zur geleiteten Wachstumskontrolle bei der Skoliose. Die Operation besteht in der Resektion der Epiphysenplatte und des Diskus bis zur halben Ausdehnung des Wirbels and der konvexen Seite der Skoliose. Die Operation wird mittels eines transthorakalen Zuganges ausgeführt.

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SCOLIOSIS

A Method for Fusion with Early Mobilization of the Patient

By

IVAR ALVIK

The aim of the operative treatment of the increasing scoliotic curve is to stop the progression of the curve, to prevent further secondary deformation, to improve the stabilization and the whole physical fitness of the patient, and if possible to correct as much as advisable the curve itself.

On account of these indications and because of the drawbacks of the ordinary methods for fusion with the long lasting immobilization in a heavy plaster jacket confined to bed for many months, partly also because of the inconvenience by operating through a window in the plaster jacket, and also because of the shortage of orthopaedic beds in our country, we started ten years ago to develop our own method for fusion of the increasing scoliotic curve.

The main principles in this method are:

1. The curve is first mobilized as much as possible by means of physiotherapy consisting of bending and streching the curve in the same way as treating a contracture. Especially important is the streching of the muscles and the soft tissue on the concave side of the curve.

2. Having obtained the best possible mobilization of the curve, a plaster jacket is applied with the patient in standing position in a gallow with suspension and side traction.

3. Further correction is obtained by means of ordinary wedging of the jacket. I admitt that it may be impossible to obtain the same correction as by using a turnbuckle jacket. But I dont think it is advisable to press the correction beyond a reasonable force. The rebending power of a curve corrected too much in this way is so strong, that no ossifica-

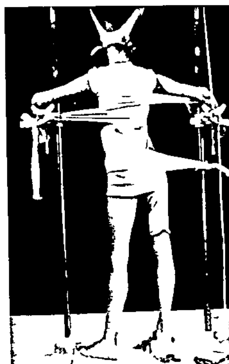


Fig 1



Fig 2

Fig 1 The patient placed in the gallow in standing position with suspension and side traction

Fig 2 The plaster jacket applied in the position shown in Fig 1



Fig 3

Wedging of the plaster jacket for further correction of the curve



Fig 4

For operation (fusion) the patient is placed on the operating table in the so called Knee Elbow position

tion and no newformed bone can stand it The consequence is development of pseudarthrosis after removal of the postoperative plaster jacket

4 The corrected plaster jacket is carried for several weeks or months and is often changed after another seance of mobilization of the curve

In cases not going to be operated upon this treatment may continue until the increasing period has subsided The mobilization and the following corrected plaster jacket may also sometimes preceed the treatment with Mecllwakes brace

5 Before the fusion the plaster jacket is removed giving access to the operating field without any hindrance

6 The operation is performed in the so called *Knee elbow position* This position is convenient for the surgeon and facilitates the operation The bleeding is also minimal in this position compared to the usual prone position with more or less of the body weight pressing on the abdominal wall

The fusion is done *in one stage* and the whole curve is included the fused area The corresponding intervertebral joints are resected

To obtain a broad boneplate after the fusion the soft tissue is stripped well off to both sides

A large amount of bone bank bone is used as chips usually more than half a liter for each fusion

7 After the operation the patient is placed back in bed without any plaster jacket and without any corrective spine support

8 The patient is usually let out of bed the third or fourth day after the operation without any spine support

9 As soon as the patient is able to stand in the gallow for at least 20 min he is replaced there with suspension and side traction as before the operation and another plaster jacket is applied in the same way as previously This is done about 14 days after the operation sometimes a little later but has to be done before the new formed bone is going to be calcified The procedure is surprisingly well tolerated and further correction of the curve is also this time obtained by means of ordinary wedging of the jacket The corrective force used by the wedging should not be greater than the corresponding force used before the operation

10 With this plaster jacket the patient is sent home can walk around attend school and maintain activity

11 The plaster jacket is worn for 9 months some times a little longer After removal of the jacket an X ray control is taken in standing position one exposure with weightbearing (the weight of the body) and another in suspension in the same way as before the operation A similar control is taken half a year after removal of the postoperative plaster jacket and once a year later

TABLE 1

Scoliotic patients treated by means of fusion at Sophies Minde Oslo University Orthopaedic Hospital from 1952 to 1960

Number 152

	Females 103	Males 49	
Etiology			
	Poliomyelitis	9	(71 right and 24 left)
	Idiopathic	52	(44 right and 8 left)
	Congenital	5	(2 right and 3 left)

From 1952 till 1960 152 patients *have been treated with fusion of the* scoliotic curve at Sophies Minde Oslo University Orthopaedic Hospital The first few cases were treated with correction in the turnbucklejacket and operation through a window in the jacket All the others were treated in accordance to the described method of correction and fusion

In the course of the first years in this period 20 of the youngest patients were treated with hemilateral fusion The fusion in these cases was carried out just on the convex side of the curve assuming that the



Fig 4
For operation (fusion) the patient is placed on the operating table in the so called Knee Elbow position

tion and no newformed bone can stand it The consequence is development of pseudarthrosis after removal of the postoperative plaster jacket

4 The corrected plaster jacket is carried for several weeks or months and is often changed after another seance of mobilization of the curve In cases not going to be operated upon this treatment may continue until the increasing period has subsided The mobilization and the following corrected plaster jacket may also sometimes preced the treatment with Meellwaikey brace

5 Before the fusion the plaster jacket is removed giving access to the operating field without any hindrance

6 The operation is performed in the so called *Knee elbow position* This position is convenient for the surgeon and facilitates the operation The bleeding is also minimal in this position compared to the usual prone position with more or less of the body weight pressing on the abdominal wall

The fusion is done in one stage and the whole curve is included the fused area The corresponding intervertebral joints are resected

To obtain a broad boneplate after the fusion the soft tissue is stripped well off to both sides

A large amount of bone bank bone is used as chips usually more than halt a liter for each fusion

7 After the operation the patient is placed back in bed without any plaster jacket and without any corrective spine support

TABLE 3

Number of vertebrae included in the fusion

4 vertebrae fused in 1 case	10 vertebrae fused in 1[illegible] case
5 vertebrae fused in 3 cases	11 vertebrae fused in 11 cases
6 vertebrae fused in 4 cases	12 vertebrae fused in 26 cases
7 vertebrae fused in 7 cases	13 vertebrae fused in 31 case
8 vertebrae fused in 3 cases	14 vertebrae fused in 28 cases
9 vertebrae fused in 12 cases	15 vertebrae fused in 7 cases
	152 cases

TABLE 4

Observation time

1.5–2 years	44
2–3 years	55
3–4 years	20
4–5 years	16
5–6 years	11
	146

TABLE 5

Follow up

Follow up examinated	146
Dead postoperatively	0
Dead later on	4
Refused follow up examination	2
	152

1 dead of bronchopneumonia 2 months after the operation
1 dead of Asiasske (probably bronchopneumonia) 1 year after op.
1 dead of bronchopneumonia 1 year after the op.
1 dead of pneumonia 3 years after the operation
These were all polio cases with pronounced respiratory paralysis

Table 2 shows that the fusion usually has been performed at the age of 13–15 years, and Table 3 shows that in most cases the number of fused vertebrae were from 12 to 14.

More or less correction is obtained in about 80 % compared to the curve before operation. This is the final result estimated at the later controls and is not referring to the correction just after removal of the postoperative plaster jacket.

TABLE 6

Final result of 146 fused scoliosis in accordance to correction of the curve

Correction obtained	116	79.5 %
Unchanged (+ — 2 degrees)	10	6.8 %
Curve increased (9 pseudarthrosis)	20	13.7 %
	146	100.0 %

TABLE 7

Final obtained correction measured in degrees

Under 6 degrees	9 cases	26–30 degrees	12 cases
6–10 degrees	22 cases	31–35 degrees	7 cases
11–15 degrees	27 cases	36–40 degrees	4 cases
16–20 degrees	18 cases	41–45 degrees	2 cases
21–25 degrees	14 cases	46–50 degrees	1 case
			116 cases

It is evident that in most cases some of the correction is lost after removal of the postoperative plaster jacket. There is, however, no loss at all in 39 cases and a loss of less than 5 degrees in 45 cases. The average loss of correction after removal the postoperative plaster jacket is 6.3 degrees included 9 cases of pseudarthrosis. (Pseudarthrosis rate 6.2 %.)

TABLE 8

Changing of the curve from the time when the plaster jacket was removed (9 months after the operation) till the follow up examination

Decreased (further correction)	11 cases	
Unchanged	28 cases	
Increased curve (loss of correction)		
0–5 degrees	45 cases	
6–10 degrees	23 cases	
11–15 degrees	11 cases	
16–20 degrees	6 cases	
over 20 degrees	15 cases	(9 pseudarthrosis)
	145 cases	

Average loss of obtained correction from removing the plaster jacket till follow up examination = *6.3 degrees*

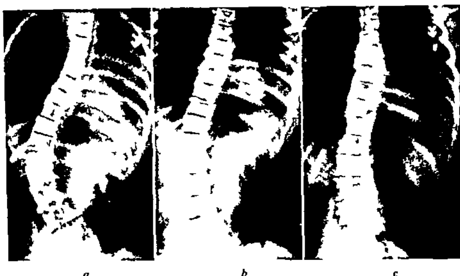


Fig 5

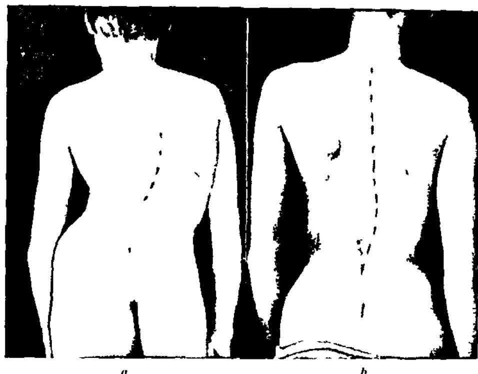
a) The spine in standing position with body weightbearing
b) The same spine in standing position suspended after mobilizing
c) The same spine after fusion

Fig 5a shows a scoliotic spine on the X ray film in standing position with body weightbearing b) the same spine in standing position and suspended after mobilizing and c) the same spine in standing position after fusion

SUMMARY

The first step in the surgical treatment of the scoliotic curve is forcible mobilization by means of physiotherapy After that a corrective plaster jacket is applied in standing position with suspension and side traction and the jacket is further corrected by means of ordinary wedging For fusion the plasterjacket is removed the patient is placed on the operating table in the so called Knee Elbow position" and returned to bed without any kind of spine support The patient is let out of bed in the course of the first three or four days after the operation and a new corrective plaster jacket is applied in the standing position with suspension and side traction as soon as the patient can stand in the gallow usually about 14 days after operation With this jacket he is sent home to school and activity for 9 months

The number of fused vertebrae were usually from 12 to 14 all in one



a *b*

Fig. 6
a) The patient before treatment
b) After fusion

sequence. More or less permanent correction of the curve is obtained in 80 %. The pseudarthrosis rate has been 6.2 %. The average loss of correction after removal of the postoperative plaster jacket has been 6.3 degrees (including the pseudarthroses). There has been no loss at all in 39 out of 152 cases.

RÉSUMÉ

Le premier pas dans le traitement chirurgical de la courbure scoliotique est la mobilisation forcee au moyen de la physiotherapie. Apres cela on utilise un corset platre correctif mis en place en position verticale avec suspension et traction de cote, le corset etant corrige plus tard par les moyens ordinaires de feutrage. Pour operer la fusion, le corset platré est retire, le malade est place sur la table d'operation dans la position dite « genou coude » et il est replace dans son lit sans aucune sorte de soutien de la colonne vertébrale. Le malade est sorti du lit au

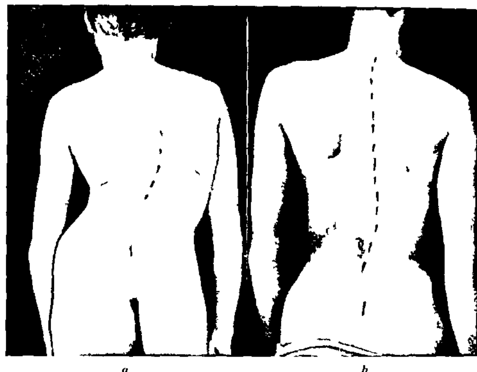
bout de trois ou quatre jours apres l operation et un nouveau corset platre correctif est mis en place en position verticale avec suspension et traction de cote des que le malade peut supporter la bretele en general 14 jours apres l operation Muni du corset il est renvoye a la maison il peut retourner a l ecole ou reprendre son activite pour une periode de neuf mois

Habituellement le nombre des vertebres fusionnees a ete de 12 a 14 toutes dans la meme séance Une correction plus ou moins permanente de la courbure a ete obtenue dans 80 % des cas Le taux de la pseudarthrose a ete de 6,2 % La perte moyenne de correction apres que le corset platre post operatoire ait ete retire a ete de 6 3 degres (y compris la pseudarthrose) Dans 39 des 152 cas il n y a pas eu de perte du tout

ZUSAMMENFASSUNG

Der erste Schritt in der chirurgischen Behandlung der skoliotischen Krummung ist die wirksame Mobilisierung mittels Physiotherapie Danach wird ein korrigierendes Gipsmieder in stehender Stellung unter Suspension und Seitenzug angelegt und das Mieder wird weiterhin mittels der gelaufigen Anbringung von Keilen korrigiert Fur die operative Versteifung wird das Gipskorsett entfernt der Patient wird auf den Operationstisch in die sogenannte Knie Ellbogenlage gebracht und ohne irgendeine Art der Wirbelsaulenunterstutzung ins Bett zuruckgelegt Im Verlaufe der ersten drei oder vier Tage nach der Operation wird der Patient aus dem Bett geführt und ein neues korrigierendes Gipskorsett wird in stehender Stellung unter Suspension und Seitenzug sobald der Patient im Galgen stehen kann gewöhnlich ungefahr 14 Tage nach der Operation angelegt Mit diesem Mieder wird er fur 9 Monate nach Hause zur Schule und zur gewohnlichen Beschäftigung entlassen

Die Zahl der versteiften Wirbel betrug meist 12 bis 14 in einer Sitzung Mehr oder weniger dauernde Korrektur der Krummung wird in 80 % erhalten Pseudarthrosen traten in 6 2 % auf Der durchschnittliche Verlust an Korrektur nach Entfernung des Gipsmieders war 6 3 Grade (einschliesslich der Pseudarthrosen) In 39 von 152 Fallen kam es zu keinerlei Verminderung der Korrektur



a *b*

Fig. 6.
a) The patient before treatment.
b) After fusion.

sequence. More or less permanent correction of the curve is obtained in 80 %. The pseudarthrosis rate has been 6.2 %. The average loss of correction after removal of the postoperative plaster jacket has been 6.3 degrees (including the pseudarthroses). There has been no loss at all in 39 out of 152 cases.

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Le premier pas dans le traitement chirurgical de la courbure scoliotique est la mobilisation forcée au moyen de la physiothérapie. Après cela on utilise un corset plâtre correctif mis en place en position verticale avec suspension et traction de côté, le corset étant corrigé plus tard par les moyens ordinaires de feutrage. Pour opérer la fusion le corset plâtre est retiré, le malade est placé sur la table d'opération dans la position dite « genou coudé » et il est replacé dans son lit sans aucune sorte de soutien de la colonne vertébrale. Le malade est sorti du lit au

ruptures in the interspinous ligaments occur during these years (*Rissanen* 1960).

The intervertebral discs and interspinous ligaments of the LIII–LIV, LIV–LV and LV–SI spaces were examined. Thus a total of 90 intervertebral discs and the same number of interspinous ligaments were studied. The lower part of the spine from the third lumbar vertebra to the sacrum, including the spinous processes, was detached and examined macroscopically. The specimens for microscopic study were fixed in 10 per cent neutral formalin and decalcified by the EDTA method (ethylene diamine tetra acetic acid disodium salt, e.g. *Dotti et al.* 1951, *Sreebny & Nikiforuk* 1951) at 37° C and pH 7.2–7.4 of the solution. The sections were stained by the Weigert van Gieson technique (*Romeis* 1948). In addition, Sudan IV (*Gatenby & Painter* 1946), Kossa's silver (*Romeis* 1948), Alcian blue (*Lison* 1954) and toluidine blue staining was performed for more detailed examination of the different changes.

RESULTS

Macroscopic Changes

For comparison of observed changes in the ligaments and discs they were classified into three groups on the basis of the gross observation: (1) no macroscopic changes from the normal structure, (2) mild degenerative changes, (3) pronounced degenerative changes. The criteria for mild changes were some degree of thickening of the ligament clearly visible to the naked eye, with the loose connective tissue distinctly proliferated but the true tendinous tissue decreased, and possibly in addition small beginnings of cavitation in the center of the ligament. In the group of pronounced degenerative changes I included the cases with a large cavity within the ligament which gave it the external appearance of marked thickening, and furthermore the cases in which a partial or complete rupture was demonstrable in the interspinous ligament.

The intervertebral discs placed in group 2 were those in which the nucleus in the cross section of the disc was abnormally firm and the disc showed pigment aggregation, distinct fissure formations and possibly small incipient cavity formations within the disc. In group 3 I included the cases with large fissures and cavities within the disc either in the nucleus or the annulus, ruptures in the annulus and considerable changes in the macroscopic structure of the disc as a whole.

The interspinous ligaments examined were distributed as follows between the different groups

	No Changes	Mild Degenerative Changes	Pronounced Degenerative Changes
LIII-LIV	16	7	7
LIV-LV	3	13	14 (2 ruptures)
LV-SI	6	9	15 (7 ruptures)

The discs examined were distributed between the different groups as follows

	No Changes	Mild Degenerative Changes	Pronounced Degenerative Changes
LIII LIV	18	7	5
LIV-LV	8	9	13
LV-SI	9	9	12

Comparison of the gross changes and their degree of severity in the interspinous ligaments and the intervertebral discs definitely reveals in 70 out of 90 cases the same degree of severity in the disc and in the corresponding interspinous ligament A slight inconsistency was found in 20 cases between the changes in the ligament and the disc the disc changes being interpreted in nearly all cases as less marked than the changes in the corresponding interspinous ligament



Fig 1

Photograph of the intervertebral discs of the LV SI (A) and LIV LV (B) spaces in a woman aged 39 Pronounced degenerative changes and total rupture were found in the interspinous ligament of the LV SI space but the ligament in the LIV LV space was intact The disc of the LV SI space appears to be degenerated and shows ruptures and defects in the area of both the annulus and the nucleus pulposus, whereas the disc of the LIV LV space appears normal to the naked eye

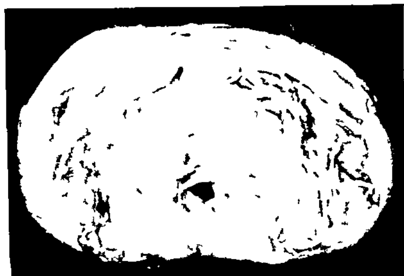


Fig 2

Intervertebral disc of the LV SI space in a woman of 61 There were total rupture and pronounced degenerative changes in the corresponding interspinous ligament The disc shows pronounced degenerative changes ruptures and defects in the annulus

The changes and their uniformity in the ligament and the corresponding disc were very distinct in the majority of the cases (Fig 1) When highly pronounced degenerative changes had occurred in the interspinous ligaments giving rise to a large cavity in the ligament with almost complete disappearance of the true ligament tissue the disc also showed ruptures in the annulus and fissure and cavity formation

The material studied contained 2 pathological ruptures in the interspinous ligaments of the LIV LV space and 7 in the ligaments of the LV SI space making a total of 9 ruptures The corresponding intervertebral disc was very markedly degenerated in all these cases Each revealed major or minor ruptures in all the layers of the annulus throughout the disc Cavities and defects of various sizes were found inside the discs (Figs 1 and 2) However I did not encounter a single clearly definite disc prolapse among these 9 ruptures either protrusion of the nucleus pulposus or of the annulus even if one of these cases displayed a slight and indistinct local bulging of the outermost fibres of the annulus which could not definitely be regarded as a manifest prolapse However all these cases had so many ruptures and fissures

in the area of the annulus fibrosus that prolapse of the disc probably could have occurred under suitable conditions Such ruptures and fissures in the annulus fibrosus were also seen in cases with no true ruptures in the corresponding interspinous ligaments but the latter were then always markedly degenerated

Microscopical Changes

Numerous descriptions of the pathological histology of disc degeneration have been published in various countries (*Bohmig* 1929 *Smith* 1931 *Donohue* 1939 *Coventry et al* 1945 *Alvik* 1950 *Hirsch & Schajowicz* 1952 *Malinsky* 1958 etc) All the types of disc degeneration described were encountered in the present material in varying degrees of severity Fatty degeneration was very common in disc degeneration In cases with gross distinct degenerative changes the fatty degeneration was often very pronounced (Fig 3) especially in the region of the annulus fibrosus The fatty substances usually accumulated as foci adjacent with other degenerative changes

In the cases in which no definitely degenerative changes were seen



Fig 3

Sudan IV staining of the intervertebral disc of the LV SI space in a man of 57 The disc was degenerated and the corresponding interspinous ligament showed marked degenerative changes and partial rupture A site of heavy lipid staining is seen in the area of the annulus



Fig 4

Alcian blue staining of the intervertebral disc of the L5 S1 space in a man of 57. The disc was degenerated and the corresponding interspinous ligament was ruptured. A typical cystic formation filled with a homogeneous mass staining bluish green is seen in the middle of the fibres of the annulus

grossly the microscopic examination revealed a decrease in the number of nuclei and weakening of the stainability of the tissue components by the van Gieson technique. When the disc degeneration was visible to the naked eye the changes brought out by this staining were also pronounced. Here and there were areas of completely necrotized tissue leaving minor or major defects in the microscopic picture. The largest of them could be seen grossly as cavities in longitudinal sections. More marked aggregation of fat was often revealed by Sudan IV staining in the tissues around these microscopic cavities.

Microscopically the degenerated discs showed here and there areas of very homogenous appearance and in places either longish or oval cystic formations filled with an amorphous or slightly granular mass. These formations stained metachromatically with toluidine blue and blue green with Alcian blue (Fig 4). These homogenous looking areas and the fissure and cyst formations thus contained substances of the mucopolysaccharide group.

Marked proliferation of small calibre blood vessels was very often demonstrable in the degenerated discs especially inside and on the margins of gross cavities. Since a normal disc has no blood vessels this phenomenon was even more pronounced by contrast (Fig 5). Prolife



Fig. 5.

Weigert van Gieson staining of the intervertebral disc of the LV–SI space in a man of 46. A rupture was present in the corresponding interspinous ligament. Photomicrograph shows part of the margin of a cavity in the disc containing numerous smallcalibre blood vessels and new cell formation.

ration of the cell components of granulation tissue was seen around the capillaries. A mesothelium-like lining was seen here and there at the cavity margins. Tissue distinctly similar to hyaline cartilage was occasionally demonstrable; this tissue resembled articular cartilage.

All the degeneration phenomena described above were of exactly the same type in the microscopic picture of degeneration and pathologic ruptures in the lowest interspinous ligaments of the lumbar spine. Ligaments with a grossly degenerated appearance in lipid staining revealed accumulations, often large ones, of a fatty substance here and there, tissue necrotization, proliferation of small-calibre blood vessels, metaplasia of tissue into tissue simulating hyaline cartilage, cavities resembling joint cavities, and accumulation of mucopolysaccharides into tissues in the area of degeneration partly diffusely, partly as cystic degeneration. The histologic and histochemical pattern of degeneration thus seems to be similar in both the disc and the corresponding interspinous ligament and usually to progress at the same rate.

DISCUSSION

In 70 out of 90 cases the *degenerative process in the interspinous* ligament was accompanied by a change of similar degree in the disc. The degenerative changes in the two structures thus seem to be concurrent and not consecutive in time. The manifestations of degeneration were similar in both tissues. It is probable that owing to the special structure of man these two tissues, the interspinous ligaments and the intervertebral discs, are subjected in the lumbar part to heavy mechanical strain. This explains in a great measure the common occurrence of *the degenerative changes, but it does not account for them fully.* Sometimes even old persons display only insignificant degenerative changes in the interspinous ligaments and the discs. Mechanical stress naturally varies in different persons, but many other factors such as hormones and vitamins may certainly have a role not yet fully known to us.

In some cases the interspinous ligaments displayed somewhat more pronounced changes than the corresponding discs. More marked lumbar *lordosis was distinctly evident in at least some of these cases.* The spinous processes were consequently brought closer to each other and the interspinous ligaments between them were subjected to heavier wear than usual, which might well account for the disproportion in question.

Nine pathological ruptures were encountered in the interspinous ligaments of the series studied. Pronounced degeneration was always demonstrable in the corresponding intervertebral disc, with greater or smaller ruptures in the annulus fibrosus. On the other hand, in none of these cases was there definite protrusion of either the nucleus pulposus or annulus. However, it must be held in mind that this was an autopsy material and that prolapse of the disc is an acute or subacute event in which remission may occur spontaneously in the course of a few weeks. Hence a study based on autopsy material warrants no definite conclusions concerning the role of pathologic ruptures of interspinous ligaments in the etiology of disc prolapse. In all cases of partial or total rupture of interspinous ligaments there were pronounced degenerative changes in the corresponding intervertebral discs, with ruptures and defects in the annulus fibrosus. Hence the preconditions for disc prolapse did exist. However, similar defects in the annulus were also established in the cases with no true rupture in the corresponding

interspinous ligament, although it displayed pronounced degenerative changes.

The investigation as a whole gave the impression that disc degeneration and degeneration of interspinous ligaments are concurrent changes that are similar in type and that possibly may also have the same etiology. Subsequent minor violence would thus be often the only condition required to produce disc prolapse and rupture of the interspinous ligaments, both of which occur in degenerated tissues. The subjects were not examined roentgenologically in the present work, but it has been shown convincingly in an extensive material (*Friberg & Hirsch* 1949) that pronounced disc degeneration can exist without being detected roentgenologically.

SUMMARY

An autopsy material was examined for pathologic changes in the intervertebral discs and the interspinous ligaments of the LIII-LIV, LIV-LV and LV-SI spaces. The observations in the two structures were compared. The series comprised 30 subjects aged 30–70, hence there were 90 discs and an equal number of interspinous ligaments. For comparison the degenerative processes seen in the discs and ligaments were classified by three degrees of severity. The conclusion was drawn that in nearly 80 per cent of cases there is degeneration of a similar degree in the interspinous ligament and the corresponding intervertebral disc. In the present series there were 9 cases of pathologic rupture of interspinous ligament, and the corresponding intervertebral disc revealed ruptures, cavities and pronounced degeneration of the annulus, but in no instances a definite prolapse. Degenerative features of exactly the same type, i.e. fatty degeneration, changes in staining properties, tissue necrosis and total disappearance of tissue, proliferation of small calibre blood vessels and cystic degeneration, were observed microscopically in the intervertebral discs and interspinous ligaments.

The conclusion reached by the author was that disc degeneration and degeneration of the interspinous ligaments are changes of the same type and concurrent development. It was not established that ligamentous changes, for instance pathologic ruptures, precede the disc changes.

RÉSUMÉ

Un matériel d'autopsie a été examiné pour étudier les modifications pathologiques des disques intervertébraux et des ligaments vertébraux

des espaces entre les vertèbres lombaires III et IV, IV et V et entre la vertèbre lombaire V et la vertèbre sacrée I. Il a été établi une comparaison entre les deux structures. La série d'observations porte sur 30 sujets âgés de 30 à 70 ans. Il y avait 90 disques et un nombre égal de ligaments vertébraux. Pour établir la comparaison, les processus dégénératifs constatés dans les disques et les ligaments ont été classés selon le degré de gravité de l'altération. La conclusion tirée est que dans presque 80 % des cas il existe une dégénération d'un degré similaire du ligament vertébral et du disque intervertébral correspondant. Dans la présente série d'observations il y avait 9 cas de rupture pathologique des ligaments avec dans les disques intervertébraux correspondants des ruptures, des cavités et une dégénération prononcée de l'anneau, mais dans aucun cas une véritable hernie discale. Des éléments dégénératifs exactement du même type, par exemple dégénération du tissu graisseux, altération des propriétés à la coloration, nécrose des tissus et disparition totale des tissus, prolifération des vaisseaux sanguins de petit calibre et dégénération cystique, ont été observés au microscope dans les disques *intervertébraux et les ligaments vertébraux.*

La conclusion de l'auteur c'est que la dégénération du disque et des ligaments sont des altérations du même type qui se développent conjointement. Il n'a pas été établi que les altérations des ligaments, par ex. les ruptures pathologiques, précèdent les altérations des disques.

ZUSAMMENFASSUNG

Ein Autopsiematerial wurde unter Hinblick auf pathologische Veränderungen der Zwischenwirbelscheiben und der ligg. interspinosa der Räume L3-4, L4-5 und L5-S1 untersucht. Die Beobachtungen, welche in beiden Strukturen gemacht wurden, wurden verglichen. Die Untersuchungsreihe umfasste 30 Personen im Alter von 30-70 Jahren. Es handelt sich daher um 90 Scheiben und um eine gleiche Anzahl von ligg. interspinosa. Zum Vergleiche wurden die an den Scheiben und Bändern gesehenen degenerativen Prozesse in drei Schwerheitsgrade eingeteilt. Man kam zu der Schlussfolgerung, dass in fast 80 % der Fälle eine Degeneration von ähnlicher Ausgeprägtheit in den ligg. interspinosa wie in den Scheiben zu finden ist. In der gegenwärtigen Reihenfolge waren 9 Fälle von pathologischen Rupturen der ligg. interspinosa vorhanden und die entsprechenden Zwischenwirbelscheiben wiesen Rupturen, Hohlräume und ausgesprochene Degeneration des Annulus, aber keinen sicheren Prolaps auf. Degenerative Zeichen von genau der

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Acta orthop Scandinav 1 66–86 1964

From the Orthopaedic Hospital of the Invalid Foundation Helsingfors Finland
(Head A Langenskiöld M D)

CAPSULAR ARTHROPLASTY (COLONNA'S OPERATION) FOR CONGENITAL DISLOCATION OF THE HIP

Results of 102 Operations

By

L F LAURENT

Arthroplasty with the joint capsule as interposition material in congenital dislocation of the hip was suggested by *Codivilla* in 1900 (4) The method was adopted by *Colonna* (5) who in 1932 reported four cases Since then in a number of articles *Colonna* has given a detailed description of the technique and indications for this operation and has reported late results of some cases (6 7 8) He recommends operation at the age of 3 to 10 years Few reports of this operation have appeared in the literature *Bertrand* (1) operated on 97 patients and obtained a good result in 70 per cent of cases *Kawamura* (12) carried out this operation in 53 cases with a poor result in 20 per cent *Schmitt* (23) gave a detailed description of 50 hips operated on at the Balgrist Clinic Zurich a good result being obtained in 40 per cent of cases In 1954 *Francillon* (10) published his experiences of a number of cases and in 1962 *Gschwend* (11) re examined the same series analysing the causes of the failures Results in small series of 19 to 26 cases have been published by *Bodart et al* (2) *Čerenanský* (3) *Ter Eguiasarov & Dolganova* (25) and *Petit & Caracostas* (19) Good results were reported in about threequarters of these cases *Francillon Bertrand* and *Petit & Caracostas* recommend shortening osteotomy of the femur in connexion with Colonna s operation in cases in which the femoral head cannot be sufficiently pulled down by traction

Dega et al (9) performed a one stage procedure which is a combination of *Colonna* s and *Zahradníček* s (26) methods Preoperative traction is not used while femoral shortening osteotomy is always carried out the antetorsion of the femur being simultaneously corrected The

authors report good results in 121 cases of 172 followed up for 2 to 4 years after this operation

Colonna's operation is a major surgical procedure with a high frequency of complications as appears from the present series too. The indications must therefore be strict, particularly since it is well known that patients with untreated luxations often remain free from pain until middle age and that the limp can be considerably improved by subtrochanteric osteotomy (13). A difference in length can be corrected by shortening osteotomy. However, to an orthopedist a luxated joint is always repugnant and he is seriously tempted to operate in cases in which closed treatment is not possible or has failed. Although in recent years there has been some improvement in the early diagnosis of congenital dislocation of the hip in Finland, a number of untreated patients aged 2 to 8 years are still remitted each year to the Orthopaedic Hospital of the Invalid Foundation. Since in most cases the age of these patients precluded any question of successful closed treatment, it was decided in 1953 to adopt Colonna's operation. During the ten year period 1951–1961 operative reduction of about 500 hips was carried out in this hospital. Part of this series was reported by me in 1953 (16).

MATERIAL

The series comprises 92 patients treated during the period 1953–1960. Colonna's operation was carried out unilaterally in 82 cases and bilaterally in 10 cases. The number of operated hips was 102. Of the patients 73 were girls and 19 boys, the proportion being 5 : 1. The nature of the deformity was as follows:

Bilateral dislocation	29
Dislocation and subluxation	17
Dislocation and dysplasia	9
Dislocation and normal	37
	92

Bilateral lesion was present in 60 per cent of cases. The annual distribution of the operations is given in Table 1.

As can be seen from the table, a larger number of operations was carried out during the period 1955–1957, while the attitude subsequently became more cautious. The age of the patients at the time of operation can be seen from Table 2.

TABLE 1

Annual distribution of operations

Year	1953	1954	1955	1956	1957	1958	1959	1960	Total
No of hips	1	12	18	38	15	7	6	5	102

TABLE 2

Age of patients at operation

Years	1–2	2–3	3–4	4–5	5–6	6–7	7–8	17	23	Total
No of patients	7	21	17	21	11	9	4	1	1	92

Operation was carried out at the age of 1 to 3 years in 28 cases at the age of 3 to 8 years in 62 cases The series also comprises two older patients

The data concern 70 hips with previously untreated dislocation 21 hips previously treated with plaster bandage in the abduction position and 11 hips which had undergone operative reduction The material thus consisted of 70 primary dislocations and 32 redislocations Most of the cases were of *McFarland* s type III Dislocated dysplastic hips

INDICATIONS

In agreement with many other orthopedists we consider that closed treatment is useless and as a rule contraindicated if the patient has reached the age of three years Between the ages of one and three years we carry out operative reduction if efforts at closed reduction have failed or if the result of the reduction is unstable In 1956 Colonna s operation was carried out on a number of patients aged one to three years in order to gain experience of the operation at this age The principal indication for Colonna s operation was dislocation in three to eight year old patients Unsuccessful treatment in plaster bandage or previous operative reduction with ensuing redislocation constituted secondary indications

METHOD OF TREATMENT

Preoperative Treatment

Colonna s operation without preoperative traction was carried out in 39 cases Low dislocation was present in most of these cases while 18 of the cases were redislocations following previous treatment The operation was preceded by traction with adhesive plaster for 2 to 5

weeks in 26 cases In 37 cases wire extension was applied often together with a pelvic plaster bandage for 2 to 4 weeks before operation These were cases of high dislocation

Preoperative *adductor tenotomy* was carried out in 33 cases

Arthrography was carried out preoperatively in 19 cases Earlier arthrography used to be carried out in a great many cases at this hospital (*Laurent* (16)) but latterly it has been performed in selected cases only If in doubtful cases one wants to find out whether there is a dislocation or a subluxation the condition of the limbus in the arthrogram is conclusive It also gives a good idea of the lateral part of the acetabular roof which is not yet ossified Contrary to *Bertrand* and *Francillon* we have not considered it necessary to carry out routine arthrography before Colonna's operation On the other hand it is no doubt important to have experience of what the arthrogram looks like in different cases

Preoperative reduction under anaesthesia was attempted in 9 cases

Operation

At Colonna's operation the same technique was used as in operative reduction This method has been described in previous publications (14 16) The skin incision is made from the spina iliaca sup ant curving to the lateral side of the femur about 5 cm distally of the greater trochanter The joint is exposed between the tensor fasciae latae and the rectus femoris muscle If necessary the incision is extended upwards and part of the insertion of the gluteus medius to the crista iliaca is divided The muscular attachment to the greater trochanter is detached together with a thin plate of cartilage The epiphyseal plate of the greater trochanter must not be injured since this may give rise to coxa valga (*Laurent* (17)) In the majority of cases the ileopsoas tendon was detached together with a piece of the lesser trochanter and transplanted to the lateral side of the femur to act as an inward rotator In any case the ileopsoas tendon often constitutes an obstacle to reduction (22) The joint capsule was mostly large enough to cover the femoral head If this was not the case the fascia lata and the limbus were used as additional material in a couple of cases The acetabulum was shaped with special chisels and a pneumatic reamer A comparatively deep and well shaped acetabulum is important for a good result This was not always achieved as will be seen later Reduction of the femoral head into the new socket sometimes proved difficult if the head

was not sufficiently pulled down by traction In such cases there often occurred as expected complications in the shape of osteochondritis Shortening osteotomy of the femur was not done After the operation the hip in Lange s position with maximal inward rotation was encased in a plaster bandage

Transposition of the ileopsoas tendon to the lateral side of the femur was carried out in connexion with the operation in 81 cases In 8 cases the tendon had already been transplanted Transposition of the ileopsoas was thus carried out in 86 per cent of cases

In congenital dislocation of the hip the femoral antetorsion is generally greater than normal In agreement with many other authors we consider that the antetorsion should be corrected when necessary Rotation osteotomy was generally carried out two to three weeks after Colonna s operation The osteotomy was made with Gigli s saw in the middle of the femur the distal portion being rotated outwards until the patella was in a frontal position The fragments were united by means of a Lane plate and four screws After the osteotomy the hip was placed in a plaster bandage for 6 weeks As a rule the plate was removed one year after the operation Correction of valgus position of the femoral neck was not carried out in the present series

Rotation osteotomy of the femur was carried out after Colonna s operation in 57 cases and before the operation in 9 cases The antetorsion was corrected through osteotomy in 65 per cent of cases

In cases of bilateral Colonna s operation the interval between the operations was 3 to 8 months

Postoperative Treatment

The patients were kept in a plaster bandage for 6 weeks after the operation or if rotation osteotomy had been carried out for 8 weeks An extension bandage with adhesive tape was then applied for 6 or 4 weeks respectively For 1 to 2 weeks the patients were then given exercises after which they were allowed to get up and walk

COMPLICATIONS

There were no fatalities in the present series Neither paresis nor any circulatory disturbances occurred in the operated extremity

Infection occurred in 4 cases In 1 of these cases osseous anchylosis occurred while in the remaining cases there was considerably limited motility in the joint The result in 3 cases was poor and in 1 fair

Fracture of the acetabulum at operation occurred in 3 cases Follow up of these cases showed considerably limited motility in the joint the result was poor

Redislocation occurred in 7 cases The cause of the redislocation was that the femoral head had not been sufficiently pulled down by the extension treatment and that the acetabulum had not been made sufficiently deep at operation In 6 cases reoperation was carried out and in 1 case closed reduction The result was good in 1 case fair in 2 and poor in 4 cases

Fibrous anchylosis occurred in 2 cases These were the oldest patients 17 and 23 years The operation is not indicated for patients of this age

Postoperative fractures occurred in 7 cases There was fracture of the femoral diaphysis in 4 cases supracondylar fracture of the femur in 1 case subtrochanteric fracture in 1 case and fracture of the crus in 1 case It is obvious that during the comparatively long period of immobilization before and after operation osteoporosis sets in which may give rise to fractures should the patient fall 6 of these fractures healed when treated with a plaster bandage In 1 case fracture of the same femur occurred three times during the course of the treatment and the fracture was finally treated by medullary nailing according to *Rush* after which it healed

Additional Operations

6 reoperations were carried out for redislocation the acetabulum being made deeper and the head being replaced To correct subluxation acetabular plasty was carried out in 3 cases after Colonna s operation Apophyseodesis of the greater trochanter was carried out in 5 cases By this operation we hope to prevent increasing coxa vara resulting from osteochondritis of the femoral head (17 20) Correction of a faulty position of the hip occurring after Colonna s operation was achieved by sub or intertrochanteric osteotomy in 3 cases

RESULTS

The results of both closed and operative treatment of congenital dislocation of the hip vary considerably in different series depending on the criteria which the authors have applied in evaluating the results (16 22 24) There is no doubt that the same criteria should be applied in different series since this would render results comparable *McFarland* (18) suggests a scheme of classification which was used in

evaluating the series presented at SICOT's congress in New York in 1960 He divided the results into five groups and considered a period of observation of 5 to 6 years necessary to enable evaluation of the results In agreement with *Scaglietti* (22) I consider a period of observation of 2 years to be as a rule sufficient for evaluation of the results After 2 years a good result is seldom impaired while a poor result never improves *McFarland*'s scheme is no doubt called for when results of early treatment are to be judged In cases of older patients who have undergone operation a normal hip is seldom achieved *McFarland*'s classification was therefore not applied when the results in the present series were evaluated The results have been divided into four groups good satisfactory fair and poor The criteria were as follows

Good Radiograms show normal or almost normal conditions in the hip The motility is normal or satisfactory by which is meant extension flexion of 180 to 80 insignificantly restricted abduction and adduction and a reduction of rotation movements to about 30 No limp

Satisfactory Slight radiological changes The head well shaped the acetabulum slightly dysplastic slightly too deep or too shallow No subluxation Motility as in the former group Limping if any is periodic and insignificant

Fair The head slightly flattened owing to osteochondritis Slight dysplasia of the acetabulum and in some cases insignificant subluxation The motility moderately limited Extension flexion 180–80 abduction and adduction 30 or more rotation considerably reduced Insignificant limp

Poor Corresponds to *McFarland*'s group 5 The hip is worse than if it had remained untreated stiff necrosis of the head and subluxation

In the three first mentioned groups the patients have no subjective symptoms Figs 1–5 shows hips classified according to this scheme

With regard to previous treatment the hips have been classified into three groups which are analysed separately

Group I This group consists of 70 hips which had not been treated earlier Attempts at reduction under anaesthesia were made in 9 cases before operation The age of the patients is seen from Table 3

TABLE 3

Age of patients at 70 primary operations

Years	1–2	2–3	3 4	4–5	5–6	6–7	7–8	Total
No of hips	7	15	10	22	9	3	4	70

The results are given in Table 4

TABLE 4
Results of 70 primary operations

Good	Satisfactory	Fair	Poor	Total
23 (33 %)	16 (23 %)	13 (19 %)	18 (25 %)	70

If the two first groups are considered good results and the two latter poor results the good results constitute 56 per cent and the poor 44 per cent of cases The results in relation to the age of the patients can be seen from Table 5

TABLE 5
Results of 70 primary operations in relation to the age of patients

Years	1–2	2 3	3–4	4–5	5 6	6–7	7 8	Total
Good	4	5	4	6	2	1	1	23
Satisfactory	1	6	–	6	2	1	–	16
Fair	1	1	1	7	2	1	–	13
Poor	1	3	5	3	3	–	3	18
	7	15	10	22	9	3	4	70

The best results were obtained between the ages of 1 and 3 years while between 3 and 7 years good results were obtained in a little over half the cases The results in relation to the length of the period of observation are seen in Table 6

TABLE 6
Results of 70 primary operations in relation to follow up time

Years	Good	Satisfactory	Fair	Poor	Total
2	5	1	–	2	8
3	3	1	3	4	11
4	3	1	5	3	12
5	6	11	3	3	23
6	5	2	1	5	13
7	1	–	1	1	3
	23	16	13	18	70

It appears from the table that after a period of observation of less than 5 years the results are considerably poorer than after a longer period of observation This does not mean that the hips have improved after 5 years but it is due to the fact that in 1956 a greater number of

patients aged 1 to 3 years was operated on and at this age the results are better.

The influence of preoperative extension treatment on the results is analysed in Table 7. Of the hips primarily operated on, 38 were cases of high dislocation and 32 of low dislocation. The majority of the hips operated on without extension treatment were cases of low dislocation; the hips which had been treated with extension with the aid of adhesive tape were high dislocations in about half and low in about half the cases, while the group which had been preoperatively treated with wire extension had, as a rule, high dislocation.

TABLE 7

The influence of preoperative traction on the results of 70 primary operations

	Good	Satisf	Fair	Poor	Total
No traction	7	7	4	3	21
Traction with adhesive tape	9	2	4	6	21
Wire traction	7	7	5	9	28
	23	16	13	18	70

TABLE 8

Results of 70 primary operations in relation to osteochondritis of the femoral head after operation

	Good	Satisf	Fair	Poor	Total
Osteochondritis absent	22	10	7	3	42
Osteochondritis present	1	6	6	15	28
	23	16	13	18	70

At first glance it appears surprising that the best results were obtained in cases in which no traction treatment preceded operation. This, however, is due to the fact that these were low dislocations, i.e. the prognostically most favourable cases, in which the incidence of osteochondritis was lowest.

When considering the modelling of the socket at operation in relation to the results, it appeared that the best results were obtained when the socket had been made comparatively deep, while when the socket was shallow, subluxation was common and redislocation occurred in two cases.

Osteochondritis of the femoral head constituted the commonest and most serious complication. Osteochondritis results from too high a pressure upon the femoral head in the new socket. This happens in



Fig 1
High dislocation Primary operation at the age of five years Result good seven years later The ileopsoas tendon has been attached to the greater trochanter with a staple



Fig 2
High dislocation Primary operation at the age of three years Result good five years later

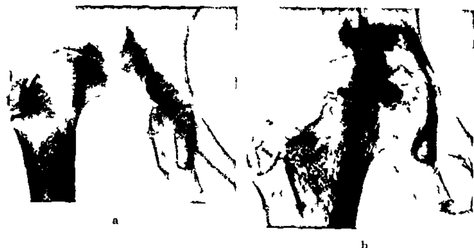


Fig 6

At the age of one year this girl was treated in an abduction plaster cast for five months Redislocation occurred and at the age of six she was admitted to this hospital for operation Result good five years later

Group III This group consists of 11 hips on which operative reduction had been carried out but redislocation had subsequently taken place The result was fair in 5 and poor in 6 hips All patients showed signs of osteochondritis in the femoral head before Colonna's operation and a deterioration of this condition was common after operation

Bilateral Colonna operation was carried out in 10 cases the number of hips being 20 The result was good in 5 hips satisfactory in 5 fair in 6 and poor in 4 hips The results were better between the ages of 2 and 5 years but as a rule poor by 6 to 7 years Fig 7 shows a result which was classified as good

Treatment of the *contralateral hip* Dysplasia was present in 9 cases but the hips as a rule normalized spontaneously Subluxation occurred in 17 cases In 3 cases operative reduction was carried out in 2 cases acetabular plasty while 2 cases were treated conservatively with a plaster bandage In the untreated subluxations there was as a rule spontaneous improvement Of 29 patients with bilateral dislocation 10 were operated on bilaterally according to Colonna Of the remaining 19 hips 12 were treated with operative reduction 1 with subtrochanteric osteotomy 1 conservatively with a plaster bandage and 5 hips were not treated at all mostly owing to complications in the operated hip

A combination of the three groups provides a survey of the entire



Fig 7

Bilateral operation at the age of four years. Result good three years later

material which consists of 102 hips. The period of observation for the whole series is seen from Table 10.

The period of observation exceeded 5 years in 63 cases (62 per cent) and was 2 to 4 years in 39 cases (38 per cent).

The incidence of osteochondritis in the whole series is seen in Table 11.

The incidence of osteochondritis was 45 per cent.

TABLE 10

Follow up time for 102 hips treated by capsular arthroplasty

Years	2	3	4	5	6	7	Total
No of hips	12	13	14	35	21	7	102

TABLE 11

Incidence of epiphyseal changes of the femoral head in 102 hips

	Osteo chondritis absent	Osteo chondritis present	Total
Primary operation	42 (60 %)	28 (40 %)	70
Earlier plaster treatment	11	10	21
Earlier operation	3	8	11
	56 (55 %)	46 (45 %)	102

TABLE 12

Results of 102 hips treated by capsular arthroplasty

	Good	Satisf	Fair	Poor	Total
Primary operation	23	16	13	18	70
Earlier plaster treatment	3	4	4	10	21
Earlier operation	–	–	5	6	11
	26	20	22	34	102
	45 %		55 %		

The results of Colonna's operation in the different groups are combined in Table 12

Good and satisfactory results were thus obtained in 46 cases (45 per cent) while the result was poor in 56 cases (55 per cent)

DISCUSSION

Our results agree fairly well with those reported by *Schmitt* (23) from the Balgrist Clinic in Zurich where he states that 40 per cent of the results were good It is obvious as is also suggested by *Schmitt* that the criteria for the evaluation of results vary

Colonna is well aware of the risk of complications and it is probable that if the rules he lays down in his papers are strictly adhered to the frequency of poor results can be reduced As appears from the fore going osteochondritis is the commonest complication leading to a poor result *Colonna* maintains that if by means of preoperative extension

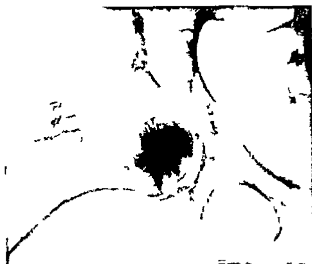


Fig 8

Five year old girl with high dislocation Control roentgenogram during the operation The femoral head is reduced into the deepened socket The epiphyseal line is situated inside the corner of the acetabular roof This in my opinion proves that the socket is sufficiently deep The result in this case was good (Fig 1)

treatment the femoral head has not been brought down to the level of the acetabulum operation should be refrained from It is possible that in such cases pressure necrosis of the head could be prevented by shortening osteotomy of the femur (1 9 10 19) We have no experience of this

The present material shows that the socket should be made comparatively deep a fact which is also stressed by *Colonna* There is a risk of fracture of the socket however This complication was responsible for the poor result in 3 of our cases Subluxation and redislocation are common complications if the acetabulum is made too shallow It is not always easy to calculate the depth of the socket at operation As a routine measure we have always taken a control radiogram during the operation after reduction of the head into the new socket But owing to the fact that the part of the head of the acetabular roof which has not yet been ossified does not appear in the radiogram the depth cannot always be estimated correctly I have found one useful criterion to be the relation of the epiphyseal line of the head to the lateral corner of the acetabular roof in the radiogram In the radiogram this line should be projected just inside the corner of the acetabular roof (Fig 8)

The operations in the present series were carried out by eight dif

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greater trochanter He stresses the importance of wire traction and shortening osteotomy of the femur if the head is not situated low enough Valgus position and antetorsion must be corrected The socket must be made sufficiently deep He further recommends postoperative extension treatment during 6 to 8 weeks and a Thomas splint for half a year

I entirely agree with *Gschwend* and *Colonna* that the preoperative extension treatment should be adequate the socket must be made sufficiently deep and that weight bearing must not be permitted too early

If complications are prevented by adequate pre and postoperative treatment and correct modelling of the socket Colonna's operation will give good results

SUMMARY

The results of 102 Colonna operations are analysed The period of observation was 2 to 7 years The age of the patients was 1 to 7 years and in addition two older patients were operated on With the exception of attempts at reduction under anaesthesia in 9 cases 70 hips had had no preoperative treatment The result was good in 23 cases satisfactory in 16 fair in 13 and poor in 18 cases On average the result was good in 56 and poor in 44 per cent of cases Owing to redislocation after treatment in a plaster bandage Colonna's operation was carried out in 21 cases A good result was obtained in one third of these cases This operation was carried out on 11 hips because of redislocation following operative reduction The result was poor in these cases The antetorsion was corrected by rotation osteotomy in 65 per cent of cases Transposition of the iliopsoas tendon to the lateral side of the femur was carried out in 86 per cent of cases The causes of the poor results are analysed The commonest complication leading to a poor result was osteochondritis of the femoral head seen in 40 per cent of cases This was due to failure of the preoperative extension treatment to bring the femoral head to a sufficiently distal position The socket must be made sufficiently deep for a too shallow socket leads to subluxation or redislocation Weight bearing should not be permitted too early By adequate pre and postoperative treatment and correct modelling of the acetabulum excellent results were obtained with Colonna's operation The operation is therefore well worth making in cases in which owing to the patient's age results cannot be expected from closed or operative reduction

The investigation was supported by a grant from the Sigrid Jusélius Foundation

RESUME

Les resultats de 102 operations par la methode Colonna sont analyses La periode d observation a ete de 2 a 7 ans Les malades etaient ages de 1 a 7 ans deux malades plus agés avant ete operes A l exception de tentatives de reduction sous anesthesie dans 9 cas 70 hanches n avaient pas éte soumises a un traitement pre operatoire Le resultat a ete bon dans 23 cas satisfaisant dans 16 pietre dans 13 et mauvais dans 18 cas En moyenne le resultat a ete bon dans 56 pour cent et mauvais dans 44 pour cent des cas Par suite d une nouvelle dislocation apres un traitement par bandage platre l operation Colonna a eté pratiquee dans 21 cas Un bon resultat a ete obtenu dans un tiers de ces cas L operation a ete pratiquee sur 11 hanches par suite d une nouvelle dislocation apres une operation de reduction Dans ce cas le resultat a ete mauvais L antetorsion a eté corrigee par osteotomie de rotation dans 65 pour cent des cas Une transposition du tendon ileo psoas du coté lateral du fémur a ete pratiquee dans 86 pour cent des cas Les causes des mauvais resultats sont analysees La complication la plus courante menant a un mauvais resultat a eté l osteochondrite de la tête femorale constatee dans 40 pour cent des cas Elle était due au défaut d un traitement d extension pre operatoire pour amener la tete femorale dans une position suffisamment distale L emboiture doit etre suffisamment profonde car si elle est trop superficielle elle conduit a la subluxation ou a la rédislocation Il ne faut pas permettre trop tot le port du poids Par un traitement pre et post operatoire adequat et par le modelage correctif de la cavité cotyloide d excellents resultats ont eté obtenus au moyen de l operation Colonna C est pourquoi il vaut la peine de pratiquer cette opération dans les cas chez lesquels en raison de l age du malade on ne peut pas s attendre a ce que la reduction fermee ou operatoire donne des resultats

ZUSAMMENFASSUNG

Die Ergebnisse in 102 Colonna Operationen werden analysiert Der Beobachtungszeitraum war 2 bis 7 Jahre Das Alter der Patienten war 1 bis 7 Jahre und ausserdem wurden 2 ältere Patienten operiert Mit Ausnahme von Einrenkungsversuchen in Narkose bei 9 Fallen hatten 70 Huften keinerlei Behandlung vor der Operation Das Ergebnis war in 23 Fallen gut in 16 zufriedenstellend annehmbar in 13 und schlecht in 18 Fallen Im Durchschnitt war das Resultat gut in 56 Prozent und schlecht in 44 Prozent der Falle Wegen Reluxation nach Behandlung

im Gipsverband wurde Colonnas Operation in 21 Fällen ausgeführt Ein gutes Ergebnis wurde in einem Drittel der Fälle erzielt Die Operation wurde an 11 Hüften wegen Reluxation nach blutiger Reposition vorgenommen Das Ergebnis was schlecht in diesen Fällen Die Antetorsion wurde mittels Rotationsosteotomie in 65 Prozent der Fälle korrigiert Transposition der Ileopsoassehne auf die Lateralseite des Femurs wurde in 86 Prozent der Fälle ausgeführt Die Ursachen der schlechten Ergebnisse werden analysiert Die häufigste Komplikation die zu schlechten Resultaten führte war die Osteochondritis des Femurkopfes Sie wurde in 40 Prozent der Fälle beobachtet Dies ist dem Mangel einer präoperativen Extensionsbehandlung die den Femurkopf in eine genügende distale Lage bringen sollte zuzuschreiben Die Pfanne muss genügend tief gemacht werden da eine zu seichte Pfanne zur Subluxation oder Reluxation führt Zeitige Belastung sollte nicht gestattet werden Bei angemessener prä und postoperativer Behandlung und richtiger Modellierung des Acetabulum wurden ausgezeichnete Ergebnisse mit Colonnas Operation erhalten Es lohnt sich daher die Operation in Fällen auszuführen in denen wegen des Alters des Patienten ein Erfolg von einer unblutigen oder blutigen Reposition nicht erwartet werden kann

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9 2 months The arthrodeses were performed by 18 different surgeons The average age of the patients at operation was 34 6 years with a range of 9 years to 58 years

Etiologically the series consists of

8 polio pareses
3 post traumatic pareses
2 spastic pareses
9 rheumatic polyarthrites
14 post traumatic arthroses
    5 radial fractures
    3 navicular fractures
    2 luxations
    4 laceration injuries
6 lunatomalacias
———
42

In paralyses the operation indications consisted in reduced function in polyarthritis cases the indications were pain on movement and aching and also in a number of cases reduction in function owing to volar flexion contracture With lunatomalacias and the post traumatic arthroses pain on movement and aching were also the main indications and in one case it was the wish for a more attractive position

OPERATIVE PROCEDURE

Autologous material was used in all 36 bone graft operations Bone transplantation from the radius to the base of metacarpal III was carried out in 26 cases 9 of which were combined with denudation of the cartilage radio carpally and inter carpally and 5 with a wedge osteotomy radio carpally The graft was taken in 15 cases from the tibia in 9 cases from the iliac crest and in 2 cases from the ulna and placed in a groove sawn or chiselled out The surgical method is attributed to *Brittain* but does not include the reinforcement suggested by him of 2 extra adjacent grafts (Fig 1) In the authors series only 1 bone graft is used which corresponds to the method described by *Ely* (Fig 2)

Bone graft arthrodesis to the distal carpal row of bones was carried out in 8 cases and to the proximal carpal row in 2 cases 3 of these had grafts from the tibia 2 from the iliac crest 4 from the radius and 1 from the ulna In 2 cases the operation was combined with wedge osteo

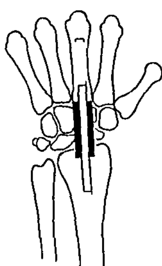



Fig 1
Operation according to Brittain
Tibia graft from the radius to metacarpal III reinforced by a further two grafts
(*Brittain* 1942)

Fig 2
Operation according to Ely
Tibia graft from the radius to metacarpal III
(According to *Ely* 1920)

TABLE 1

Adapted surgical procedures	
Graft transplant – radius to metacarpal III	26
Graft transplant – radius to carpus	10
Cartilage resection only – radio-carpally and intercarpally	4
Wedge osteotomy only – radio-carpally	2
	42

tomy in the radio carpal joint and drilling and resection of the carti lage and in 7 cases with only cartilage resection Arthrodesis without bone graft by means of articular cartilage alone radiocarpally and in tercarpally was performed in 4 cases Wedge osteotomy only was em ployed in 2 cases (Table 1) The operations were performed under general narcosis 3) or plexus anaesthesia 7 and in a bloodless field apart from 8 cases

TABLE
Case

Record n sex	Age at op yrs	Hand op	Surgical procedure	Obs period yrs	Re- Radiological
Polio pareses					
424/38 ♀	28	left	full cartilage resection	18	Consolidated only between radius and lunate
2957/46 ♀	31	right	wedge osteotomy radio carp cartilage resec intercarp tibia graft radio carp fixed by screw	12	Consolidated
4841/50 ♀	13	left	Ulna graft from radius to metacarp III + cartilage resect	10 6/12	Consolidated
3121/51 ♀	25	left	Tibia graft from radius to metacarp III + cartilage resec proxim	7	Consolidated
3366/41 ♂	42	left	Radius graft radio carpally + cart resec	18	Consolidated only between radius navicular and lunate
808/44 ♂	32	right	Tibia graft from radius to metacarp III	15	Consolidated
3832/48 ♂	19	left	Tibia graft from radius to metacarp III + wedge osteotomy radio carp	10/12	Consolidated
6366/48 ♂	32	left	Ulna graft radio carp ulnar resection wedge osteotomy radio carp + cart resection intercarp + cart destruction distally owing to drilling	11 6/12	Consolidated only between radius lunate and triquetrum
Post traumatic pareses					
48/40 ♀	17	left	Tibia graft radio carpally + ulna resection + cart resection radio carpally and intercarpally	11	Consolidated
3317/42 ♂	25	right	Radius graft from radius to navicul + full cart resection	1 6/12	Consolidated only between radius navicul and lunate

istory

lts		Wo k before after op	Remark
Cl n cal	Subj ctive		
nstable	No improvement	Housework / ditto	
tal le	No remarks	Telephonist / ditto	Post-operative fistula with spontaneous healing
able	No remarks	Student / Telephonist	
able	Considerable improvement	Nurse / Office worker (owing to other pareses)	
n table	No remarks	Assistant Supervisor / ditto	
able	No remarks	Confectioner / ditto	
l le	No remarks	Student / Dentist mechanic	Not examined
table	Hand clenching impr ved	Electrician / Telephonist	
l l	C nsiderable impro ement Occasi nally slight pain with trenu us work	Sales assistant / ditto	
t t l l	When working pain without bandage	C nstruction worker / Precisi n mechanic	Not examined

TABLE

Record no ex	Age at op yrs	Hand op	Surgical procedure	Obs period yrs	Re... Radiological
1496/49 ♂	53	right	Tibia graft from radius to metacarp III Reoper after 1 week owing to fracture of base of metacarp III graft fixed by cerclage	11	Graft fracture on level with radio carpal joint other wise consolidated
Spastic Pareses (C P)					
2869/41 ♂	16	right	Tibia graft from radius to metacarp III + wedge osteot radio carpally	11	Consolidated
3369/41 ♂	9	left	Cartilage resection radio-carpally and intercarpally	11	Consolidated
Rheumatic polyarthritis					
1013/44 ♀	27	right	Tibia graft from radius to metacarp III + wedge osteot radio-carpally	6	X ray pictures ar lacking
4062/44 ♀	30	left	Tibia graft from radius to metacarp III	13	Consolidated
1585/45 ♀	12	left	Cartilage resection radio carpally	11	Consolidated
3531/53 ♀	15	left	Tibia graft from radius to metacarpal III + cart resection radio carpally	6	Consolidated
	18	right	Iliac crest graft from radius to metac III + cartilage resection radio carpally	3	Consolidated
6158/49 ♂	52	left	Iliac crest graft from radius to metacarp *III*	8	Not consolidated *with metacarp* II
695/55 ♂	51	left	Iliac crest graft from radius to metacarp III	1 9/12	Consolidated
6375/56 ♂	36	right	Wedge osteot radio carpally	4	Consolidated
663/57 ♂	48	right	Iliac crest radio carpally cart resection chips	3	Consolidated

(cont)

lts		Work b f e after op	Rem rks
Cl nical	Subjective		
nstable	Pain	Engineer / ditto	Tibia fracture following taking of graft
table	No remarks	Student / Office worker	
able	No remarks	Student / Office worker	
able	No remarks	Invalid owing to polyarthritis in other joints	
able	No remarks	Housekeeping / ditto	
able	No remarks	Invalid owing to polyarthritis in other joints	
l l	No remarks	Office worker / Housekeeping	
al le	No remarks		
n tal le tall	No remarks	Civil servant / ditto	
al le	No remarks	Odd job man / ditto	
bl	No remarks	Foundry worker / ditto	
l l	No *remarks*	*agricultural* worker ditto	

TABLE

Record no sex	Age at op yrs	Hand op	Surgical procedure	Obs period yrs	R… Radiological
Radius fracture					
18059 ♀	56	left	Tibia graft from radius to metacarp III. Reop after 14 mths with bone chips owing to bone resorption distally	2	Not consolidated with metacarp III
850 38 ♂	47	left	Radius graft from radius to navicular + cart resection prox	1	Consolidated between radius navicular and lunate
2333/38 ♂	30	right	Radius graft radio-carpally cart resection radio-carp and intercarpally	21	Consolidated
6010/42 ♂	26	right	Tibia graft from radius to metacarp III full cart resection	10 6/12	Consolidated
37/49 ♂	44	left	Iliac crest graft from radius to metacarp III. Reop after 4 mths with tibia graft owing to graft fracture	1	Graft fracture on level with joint between lunate a… capitatum
Navicular fracture					
538/42 ♂	50	left	Tibia graft from radius to metacarpal III	6/12	Consolidated
4139/60 ♂	52	right	Iliac crest graft from radius to metacarpal III	8/12	Consolidated
3153/46 ♂	21	left	Iliac crest graft from radius to metacarpal III cart resection radio-carp + intercarpal	5/12	Consolidated
Luxatio carpi					
2701/37 ♂	49	left	Cartilage resec radio-carpally + intercarpally	23	Consolidated
3746/38 ♂	46	right	Iliac graft radio carpally	1 9/12	Consolidated only radio carpally n… between prox and dist carpal row
Laceration injury					
2080 44 ♂	26	right	Tibia graft from radius to metacarp III wedge osteot radio-carp	4/12	Consolidated

cont)

Cl nic l	Subj ti	Wo k b fo e aft r op	R m k
ble	Pain constant aching	Packing worker / Disability pension	Causalgia since the primary trauma
table	Pain	Unskilled labourer / Porter	Not examined
l le	No remarks	Painter / ditto	
l lc	No remarks	Plater / Driver	
t ble	Pain	Metal worker / Not started to work	
bl	No remarks	Waiter / ditto	Not examined
l le	No remarks	Plater / ditto	
l le	N remarks	Churnmaker / ?	Not examined
l l	No remarks	Odd job man / ditto	
table	Pain cannot do without bandage	Farm worker / Machine operator	
l	N remarks	? / ? (refugee)	Not examined

TABL

Record no sex	Age at op yrs	Hand op	Surgical procedure	Obs period yrs	Radiologic
2917/48 ♂	30	left	Tibia graft from radius to metacarp III ulna resec cartilage resec radio carpally	12	Consolidated
5862/48 ♂	26	right	Tibia graft from radius to metacarpal III wedge osteot radio carpally	11	Consolidated
3902/49 ♂	31	right	Wedge osteot intercarpally ulnar resection	11	Consolidated
Lunatomalacia					
774/49 ♂	49	right	Tibia graft radiocarpally cart resection	12	Consolidated
4485/49 ♂	27	right	Ulna graft from radius to metacarpal III	10/12	Not consolidated with metacarp
1109/50 ♂	56	right	Iliac graft from radius to metacarp III cartil resection radio carpally and intercarpally	6	Consolidated
4466/55 ♂	47	right	Tibia graft from radius to metacarpal III cartil destruction using chisel Reop with bone chips after 6 mths owing to graft fract dist	3	Not consolidated distally with metacarp III
4651/56 ♂	58	right	Iliac graft from radius to metacarpal III	11/12	Graft fract on le with carpo metacarpal joint otherwise consolidated
1010/60 ♂	50	right	Iliac graft from radius to metacarpal III Reop after 11 mths owing to graft fract in radio carpal joint with chips and osteosynthesis	1 3/12	Not consolidated in carpo metacarpal joint probab graft fract here also

(cont.)

lt		Work bef r lt r op	R m rk
Cli ical	S bjecti		
able	No remarks	Unskilled labourer / Painter	Adhesions around the extensor tendons in the op region Tenolysis 2 mths after operation
ble	No remarks Hand without function owing to pareses	Farm worker / Factory worker	Injury complicated by ulnar and median nerve lesion
ble	No remarks	Student / Preacher	
abl A part m some ment in metacarpal nt with ght pain	No remarks	Carpenter / Cleaning	Luxation trauma with navicular and styloid process fracture
tal le	Pain	Carpenter / *	Not examined
Adhesi ns nd extens r d n in the egi n	Reduce l power of finger extension Manage all his work N remarks	Builder / Office w rker	Post-op infection in the wound with graft slipping re op after 2 week
table	N remarks	Brush maker / Packer	
h r unstable the arp ta arpal j int	N remark	Lumberjack / ditto	
tal le	No remarks u e elastic bandage a upport	Un killed labourer / Painter	



Fig 3

Arthrodesis with tibia graft and very short insertion into the base of metacarpal III Left Immediately after op Right after 15 years Confectioner (808/44) fully at *work without trouble Operated on at 39 years of age owing to polio paresis* with drop hand

RESULTS

Out of 42 arthrodeses performed on 41 patients 29 (69 0 per cent) were *subjectively completely free from trouble* 4 (*9 5 per cent*) were much improved and 9 (21 4 per cent) stated that they had considerable residual trouble (Table 2) Amongst the 33 patients subjectively free from pain or much improved there were 12 who had performed heavy work before illness or trauma 5 of these returned to heavy work all with arthrodeses from the radius to the metacarpal III (Fig 3) 2 patients out of the remaining 7 changed to lighter work owing to other injuries and the 5 others did so presumably owing to causes not concerned with the arthrodesis No patient with radiocarpal arthrodesis only returned to heavy work such as lumberjacking or road work

A comparison between the subjective attitude of the patients and clinical stability showed that out of the 33 who were subjectively free from pain or improved 27 cases became stable while 8 out of the 9 cases with residual trouble were unstable

Finger mobility and pro and supination mobility were not made worse by any arthrodesis except in one case where adhesions around the extending tendons of the fingers occurred through infection (1109/50)

In 2 of the laceration injuries ulna resection of 2 cms was performed

distally and while the one remained unchanged the other improved from 45° active + 20° passive pronation and 0° supination to 80° pronation and 90° supination postoperatively actively and passively. No ulna resection was performed in the 9 polyarthritis cases. 3 maintained as before complete pro- and supination. 4 had reduced pro- and supination both before and after operation. Owing to incomplete information 2 of the cases could not be evaluated.

Actual strength measured by dynamometer was always lower on the operated side, bearing in mind left- and right-handedness. Apart from the paresis cases 5 patients showed a muscle atrophy of the lower and upper arm of 1 to 2 cms. on the operated side. The actual strength of all these considerably worse on the operated side.

The average fixation period in plaster for those cases free from complication varied from 2½ mths. for the peripheral nerve injuries, 3½ mths. for the polyarthrites and 4 mths. for the post traumatic cases to 5½ mths. for the lunatomalacias. The time for the resumption of work with or without supporting bandage varied considerably from an average of 4½ mths. for the polyarthritis cases and 8½ mths. for the post traumatic cases to 10½ mths. for the lunatomalacias.

In 11 of the post traumatic cases the decision of the insurance companies concerning the degree of invalidity was taken by reference to the result of the follow-up. Patients with stable arthrodeses who could return to their previous work received 20 per cent, while those who had changed to lighter work and were trouble-free without support obtained up to 33⅓ per cent. A higher percentage only occurred in cases with complicated injuries which reduced the use of the hand.

DISCUSSION

Method of Operation

As regards the incidence of radiologically consolidated arthrodeses no distinct difference could be demonstrated between the methods of operation utilized in the series (Table 3).

As far as subjective trouble is concerned, bone graft arthrodeses which also included the carpo-metacarpal joint seemed to produce better results than other procedures.

One would expect that the combination of bone graft arthrodesis with cartilage resection and/or wedge osteotomy would effect a more stable consolidation. This is in fact what the series indicates. 18 out of 23 arthrodeses with the combined operation consolidated as against 10

out of 19 operated without the combined procedure Omitting the poly arthritis cases which have a considerable tendency towards spontaneous ankylosis and the 2 post traumatic cases which were already almost completely stiff the following distribution is found

13 out of 17 cases with combined operations consolidated

5 out of 13 without the combined operation consolidated

In this section of the series the difference becomes more obvious

TABLE 3

The statistical comparison between surgical methods based on radiological signs of the consolidation of the arthrodesis show no significant difference

	Graft Radio metacarp III	Graft radiocarp only	Cartilage resection only	Wedge osteotomy only	
X ray consolidated	17	6	3	2	28
Not fully X ray consolidated	8	4	1	0	13
	25	10	4	2	41

Butler considered radio metacarpal arthrodesis to be superior to radiocarpal since the latter produced residual pain more often *Merle d Aubigne & Lataste* found arthrodeses between the radius and the proximal carpal row to be inadequate in scaphoideus injuries and recommended arthrodeses from the radius to the distal carpal row or the metacarpus

Abbott and his colleagues on the other hand declare that preservation of mobility carpo metacarpally is important for a flexible grip and state that all 48 radiocarpally operated on consolidated and were trouble free

Robinson & Kayfetz carried out resection of the proximal carpal row and then fixed the capitatum to the radius by means of screws All 12 cases all traumatic arthrites healed without incident Several were able to do heavy work Precise finger work was impeded however

Graft Material

In the graft fractures no distinct difference in incidence arose amongst the various transplants 2 out of 18 tibia grafts fractured and 3 out of 11 from the iliac crest fractured Out of 4 radius and 3 ulna grafts none fractured The fractured grafts all extended from the

One rheumatic case 1013/44 is missing due to no X rays

radius to metacarpal III The risk of fracture seems to be greater for grafts which pass the carpo metacarpal joint than for the shorter grafts which only reach the carpal bones Inadequate fixation of the carpo metacarpal joint was probably the cause of the graft fractures The effectiveness of the plaster fixation in the individual cases could not be judged owing to incomplete information about the plaster technique Our series does not permit the recommendation of any definite bone graft transplant The tibia graft has the disadvantage of longer post operative immobilization owing to the defect in the tibia but has the advantage probably of greater firmness One of the 18 patients operated on with tibia graft had a tibia fracture It is an open question whether iliac crest grafts produce more rapid consolidation It has been found in experimental research that cancellous bone (autologous living) brings about a more powerful stimulation of osteogenesis in the host bone and swifter revascularization than cortical bone (*Woodruff* 1960 and others) *Brittain* observed 2 fractures in 22 radio metacarpal grafts both iliac crest grafts Tibia grafts were therfore recommended re inforced by a further graft on each side (Fig 1) All these consolidated

Etiology

Patients with much arthrosis or a destructive arthritic process could be expected to have a more certain tendency towards consolidation and this is shown by the series 18 out of the 42 operated cases had con siderable arthrosis and 15 of these consolidated Only 10 out of 20 patients without arthrosis gained complete consolidation All poly arthritis cases healed without incident except one case (6158 42) which had an unstable carpometacarpal joint but remained trouble free

Age

The average age on operation for the consolidated arthroses was 30 years as against 42 for the partially consolidated and the average age of the series 34 6 years with variation from 9 to 58 years Within these limits age does not seem to constitute any contra indication *Colonna Campbell* and *Lange* (1951) advise against the operation until X rays have shown closure of the epiphysis in order to avoid growth disturbances Our 3 cases a graft operation on a 13 year old (4841/50) and cartilage resection on a 9 year old (3369 41 Fig 4) and a 12 year old (158/45) did not result in any growth disturbances



Fig 4

Arthrodesis following only cartilage resection radio carpally and intercarpally at 9 years of age owing to spastic paresis with volar contracture of the wrist joint Left Immediately after operation Right after 11 years The patient has gained much advantage functionally and cosmetically He works in an office and has no trouble (3369/41)

SUMMARY

In this study 42 wrist joint arthrodeses are presented with an average observation period of 7 5 years 29 (69 per cent) of these became completely free of trouble 4 (9 5 per cent) improved considerably and 9 (21 4 per cent) declared that they had much residual trouble

Graft arthrodeses combined with cartilage resection and/or wedge osteotomy showed a higher incidence of healing than non combined interventions In the graft fractures we found no distinct difference between iliac crest tibia ulna or radius grafts

Graft arthrodesis from radius to metacarpal III according to *Ely* seemed in our series to produce better results than other methods

RESUME

Dans ce travail il est présenté 42 arthrodèses du poignet avec une période moyenne d'observation de 7 ans et demi Parmi ces cas 29 (69 pour cent) étaient libérés de toute gêne Chez 4 (9 5 pour cent) l'état était sensiblement amélioré et chez 9 (21 4 pour cent) il continuait à avoir des inconvénients graves

Les arthrodèses ponts combinées à une résection cartilagineuse et/ou une ostéotomie cunéiforme ont montré une fréquence de guérison plus élevée que les interventions non combinées En ce qui concerne les fractures du pont nous n'avons pas trouvé de différence certaine entre les ponts de crête iliaque de tibia de cubitus ou de radius

Dans nos observations l'arthrodese pont du radius au metacarpien III d'apres *Ely* semble donner de meilleurs resultats que les autres methodes

ZUSAMMENFASSUNG

In dieser Arbeit stellt man 42 Handgelenksarthrodesen mit einer durchschnittlichen Beobachtungszeit von 7 5 Jahren vor Von diesen waren 29 (69 0 Prozent) vollkommen beschwerdefrei bedeutend gebessert 4 (9 5 Prozent) und 9 (21 4 Prozent) gaben starke fortdauernde Beschwerden an

Spahnarthrodesen die mit Knorpelresektion und oder Keilosteotomie verbunden waren zeigten eine hohere Heilungshäufigkeit auf als nicht kombinierte Fingriffe Hinsichtlich Spahnbruchen fanden wir keinen sicheren Unterschied zwischen Crista iliaca Tibia Ulna oder Radius spähnen

Die Spahnarthrodese vom Radius bis zum Metacarpale III nach *Ely* schien in unserem Material bessere Resultate zu geben als die ubrigen angewandten Methoden

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HABITUAL DISLOCATION OF THE EXTENSOR CARPI ULNARIS TENDON

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Tendon dislocations occur rarely and involve in order of frequency the tendons to the peroneus longus and brevis the extensor digitorum communis the biceps brachii the anterior and posterior tibialis and the extensor carpi ulnaris

The extensor carpi ulnaris tendon normally situated in the 6th compartment under the ligamentum carpi dorsale dislocates to the ulnar side over the styloid process of the ulna in the event of dislocation After the primary dislocation the condition becomes habitual On supination of the hand the tendon will slide into the ulnar direction while on pronation it will slide back into its normal position in the groove between the capitulum and the styloid process of the ulna The mechanism is explained by a movement in which from a position of flexion supination abduction the hand is forced into extension pronation adduction a movement similar to the backhand stroke in tennis

Searching the literature the author found only four reported cases of isolated dislocation of the extensor carpi ulnaris tendon

Schlesinger in 1907 reported the first case without known preceding injury It was treated surgically a new compartment for the tendon being created under the ligamentum carpi dorsale after detaching a flap *of periosteum from the ulna The operative result is not stated*

In 1933 *Bangerter* described a case which had arisen after a backhand stroke in tennis The patient suddenly developed severe pain on the ulnar aspect of the wrist and on supination of the hand he noted a swelling on the ulnar side accompanied by a "snap Operation was performed but the technique is not stated—and nor is the result

Markees (1937) reported a case of bilateral tendon dislocation without evidence of preceding injury The patient had complaints only from

one wrist having pain in the joint upon making extreme movements in physical exercises. At operation the extensor carpi ulnaris tendon was found to slide loosely under the ligamentum carpi dorsale sliding in supination across the ulnar styloid process under the ligament to its attachment on the ulna. The operative technique was like that used by *Schlesinger* and surgery was applied only to the wrist which gave rise to complaints. Five weeks after the operation there was free mobility in the wrist and the tendon remained in its compartment on supination.

Most recently this condition has been described by *Kohler*, in 1958 who reported a case of unilateral dislocation sustained in volleyball. After operation as described above the patient was completely relieved of discomfort which had consisted in pain on pronation supination.

PRESENT CASE

Case rec. 1471/63, a woman aged 38. While operating a washing machine the patient had to turn a vertical, downward directed handle to the horizontal position (thereby making a movement corresponding to that described above). This movement which required great strength gave rise to a "snap" in the region of the wrist and severe pain in the same site. The condition was interpreted as a distortion by the patient's doctor who treated her with a supporting bandage. However, the pain in the wrist persisted and was accentuated by housework. On supination pronation of the hand the patient still felt a "snap" in the region. Therefore the wrist was X rayed, but no skeletal abnormality was found.

When, at the end of a couple of months, the condition remained unchanged the patient was admitted to the surgical department on Aug. 13, 1962.

Physical examination showed that both extensor carpi ulnaris tendons slid in the ulnar direction across the ulnar styloid process on supination, while on pronation they slid back into their normal position. There had been no known injury in the case of the left hand which showed a normal range of movement without any complaints. On the right extension flexion was free, while active pronation supination was restricted and painful. Fixation of the tendon was therefore done on Aug. 14th. After a transverse incision into the ligamentum carpi dorsale which was incidentally intact, the proximal and distal parts of this ligament were fixed by two nylon sutures to the ulnar periosteum immediately ulnar to the normal position of the extensor carpi ulnaris

tendon This formed a "septum which prevented the tendon from sliding into the ulnar direction on supination After the skin had been sutured with nylon a circular plaster cast was applied from the knuckles to the elbow and the patient was discharged on Aug 15th The plaster cast was removed at the end of 3 weeks the wound had healed *per primam* and active exercises were started At follow up one month later the patient had no complaints and free mobility in the wrist On pronation supination the extensor carpi ulnaris tendon remained in the osseous groove between the styloid process and the capitulum of the ulna

DISCUSSION

In three of the five reported cases of dislocation of the extensor carpi ulnaris tendon there had been a history of injury In two of the five cases the dislocation was bilateral but gave rise to symptoms only on one side According to the findings it must be considered beyond doubt that injury is of aetiological significance but other factors are probably operative as well For instance a congenital anomaly cannot be ruled out

SUMMARY

A case of habitual bilateral dislocation of the extensor carpi ulnaris tendon is reported On one side it was possibly caused by injury It was treated surgically by fixation of the tendon forming a "septum At follow up 7 weeks after the operation the patient had no complaints There was unrestricted mobility in the wrist and on pronation supination the extensor carpi ulnaris tendon remained in its compartment

RESUME

Il est rendu compte d un cas de luxation habituelle du long extenseur du pouce éventuellement provoqué par un traumatisme Il a ete traité chirurgicalement avec fixation du tendon par formation de « septum » A un examen de controle sept semaines apres l operation on a constate que le malade etait entièrement liberé de symptomes qu il avait son entiere mobilite du poignet et qu en mouvement de pronation et de supination le long extenseur du pouce restait dans sa gouttiere

ZUSAMMENFASSUNG

Man berichtet einen Fall von habitueller Luxation der extensor carpi ulnaris Sehne, möglicherweise auf traumatischer Basis entstanden. Sie wurde operativ mittels der Bildung eines „Septum" behandelt. Bei der Nachuntersuchung 7 Wochen nach der Operation findet man, dass der Patient vollständig symptomfrei und das Handgelenk frei beweglich ist. Die extensor carpi ulnaris Sehne verbleibt bei der Pro- und Supination in ihrer Kulisse.

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From the Orthopaedic Hospital, Copenhagen, Department of Hand Surgery
(Head: K. Bang Rasmussen)

MENTALITY AND DYSTROPHY

By

H. Ehlers and L. Zachariae

INTRODUCTION

Dystrophy — or better "posttraumatic dystrophy" — is taken to mean the state which may arise following injuries of or surgery on a limb and which is characterized by oedema, fibrosis and stiffness as well as various vegetative disturbances. It is a serious complication which may entail permanent sequelae, but despite numerous investigations its exact cause and pathogenesis remain unelucidated and constant matters of discussion. However, there is a general feeling that the patients' mentality is a factor in the development of the syndrome. Many surgeons claim that they are able to foretell whether a patient is going to develop a state of postoperative dystrophy or not.

It was the object of the present study to try to elucidate whether the mental state actually does exert such a marked influence upon the occurrence of the dystrophic syndrome.

MATERIAL AND METHODS

At the Department of Hand Surgery of the Orthopaedic Hospital, Copenhagen, about 100 patients with Dupuytren's contracture undergo operation *per annum*. This makes up a large, uniform material. Since, moreover, patients with Dupuytren's contracture have proved particularly liable to develop postoperative oedema, fibrosis and stiffness of the hand, we chose this group for our investigations.

At first the surgeon tried to estimate, prior to the operation, whether the patients were of a type that would develop postoperative dystrophy. However, the surgeon's impression very seldom fitted, and the actual study was therefore carried out in collaboration with a psychiatrist.

Preoperatively all the patients were seen by the psychiatrist, who assessed their character and gave a statement containing a presumption

regarding the postoperative course The surgeon was not cognizant of the contents of this statement and all the patients were subjected to the same surgical procedure and after treatment A few months later the postoperative course presumed by the psychiatrist was then compared with the real course So far this study includes 33 male patients

A priori it might be expected that the traits needed to develop a state of dystrophy would be of the hysteriform martyr type nature but 2 patients with a history of dystrophy showed sthenic self asserting and querulous traits to an extent which bordered on a characterogenic paranoia and which were not believed to be secondary to operation or complications Bearing these findings and reflections in mind an attempt was made to trace—in candidates for operations on Dupuytren s contracture—sthenic self asserting traits combined with hysteriform reactions and thereby foretell a protracted postoperative course

RESULTS

As already mentioned the material comprises 33 males From the table it will be seen that 30 out of 33 had a postoperative course in conformity with that expected by the psychiatrist

In 24 cases the psychiatrist did not believe there was a risk of a protracted course Among these patients there were 5 who were normal 5 demented and old and 14 who displayed unstable traits All had a quiet postoperative course and had recovered in less than 2 months In 5 cases the psychiatrist did find traits which might be imagined to give rise to postoperative complications but these patients were not believed to possess sufficient strength of character to maintain this state for any length of time This fitted in 3 cases who had a fairly prolonged course of oedema fibrosis and stiffness but were restituted in about 3 months while 2 had a completely uneventful course

In 4 cases the psychiatrist expected a serious risk of protracted post operative complications possibly with permanent sequelae finding a sthenic character as well as the special features which are believed to make up the basis of postoperative complications These four patients will be described in some detail

No I was described as being aggressive paranoid aggrieved and self opinionated The psychiatrist feared a troublesome postoperative course And indeed the patient developed severe postoperative complications a full blown state of dystrophy and 4 months after the operation the hand was not yet fully restituted

No II was designated as a bitter dissatisfied self centred person with hysteriform traits so he was expected to develop dystrophy His postoperative complications were accurately localized to the operated finger which was stiff and swollen for a long time—and it was 4 months before he had recovered

Psychiatric assessment	No of cases	Presumed postoperative course	Actual postoperative course [illegible]	[illegible]
Normal	5	Uncomplicated	5	–
Unstable	14	Uncomplicated	14	–
Demented and arteriosclerotic	5	Uncomplicated	5	–
Aggression inhibited Defeatist attitude Self pitying Perfectionistic Non sthenic	5	Short lasting difficulties in restitution	3	?
Aggression inhibited Martyr type Self pitying Aggressive Self-opinionated Ambitious Hysterical Sthenic	4	Long lasting severe complications	3	1
Total number	33		30	3

No III was a difficult patient who was characterized as being an emotional clingy person with sexual neurosis Primarily it was not *believed that* postoperative complications *would* occur as *the* patient stated—as soon as the examination had been started—that after an operation he was suffering from urinary incontinence and always wore a diaper The psychiatrist was therefore inclined to put his abnormal features down to this account but it was later found that he was not suffering from urinary incontinence at all He must therefore be classified as an hysteriac and this affords the explanation of the protracted postoperative course of oedema fibrosis and stiffness for 4 months

No IV was described as an intelligent sthenic ambitious person with hysteriform traits who was expected to develop a state of dystrophy However in this case the postoperative course was entirely uneventful The patient was remarkably energetic in training his hand It must be presumed that for some reason or other his ambitious character has manifested itself in the striking rapidity with which he got going again while under different conditions the same traits might have given rise to dystrophy

CONCLUSION

On the basis of the present studies it may be concluded that an interested psychiatrist who has familiarized himself with these special problems can foretell with great likelihood whether postoperative complications—in the form of oedema fibrosis and stiffness—are going to occur in a candidate for surgery on Dupuytren s contracture This is of great importance both in fixing operative indications and in trying to penetrate the aetiology and pathogenesis of the condition called dystrophy

SUMMARY

The object of the present study is to try to elucidate whether the mental state of the patient influences the occurrence of postoperative dystrophic syndrome

33 male patients with Dupuytren were seen preoperatively by the psychiatrist who assessed their character and gave a statement presumption regarding the postoperative course The surgeon was not cognizant of the content of this statement

Some months after the operation the postoperative course presumed by the psychiatrist was compared with the real course

In 30 out of 33 patients there was conformity between the preoperative psychiatric statement and the real postoperative course and the conclusion is that an interested psychiatrist can foretell in a great deal of cases whether a hand operation will be complicated by postoperative dystrophic symptoms or not

RESUME

L objet de la presente étude est d essayer d etablir si l etat mental du malade presente une influence par rapport a l apparition d un syndrome dystrophique post operatoire

33 hommes souffrant de dupuytren ont ete examines prealablement a l opération par un psychiatre qui a juge de leur caractere et donne une presomption de l evolution post opératoire Le chirurgien n avait pas connaissance de la teneur du rapport

Quelques mois apres l opération l evolution post operatoire presumee par le psychiatre a ete comparee a l evolution reelle de l etat du malade

Chez 30 des 33 malades il y avait conformite entre le rapport psychiatrique pre operatoire et l evolution post operatoire de l etat du malade La conclusion en est que dans un grand nombre de cas un psychiatre competent peut predire si une operation de la main donnera lieu a des complications dystrophiques post operatoires ou non

ZUSAMMENFASSUNG

Der Zweck der gegenwartigen Untersuchung ist zu ermitteln ob der geistige Zustand des Patienten einen Einfluss auf das Vorkommen des postoperativen dystrophischen Syndroms hat

33 mannliche Patienten mit Dupuytren wurden vor der Operation vom Psychiater untersucht der ihren Charakter beurteilte und eine Erklarung mit Hinsicht auf den mutmasslichen postoperativen Verlauf abgab Der Chirurg hatte keinerlei Kenntnis von dem Inhalt dieser Erklarung

Einige Monate nach der Operation wurde der vom Psychiater vermutete postoperative Verlauf mit dem wirklichen Verlauf verglichen

Bei 30 von 33 Patienten war eine Übereinstimmung zwischen der pre operativen psychiatrischen Aussage und dem wirklichen postoperativen Verlauf vorhanden Die Schlussfolgerung ist dass ein interessierter Psychiater in einem grossen Teil der Falle voraussagen kann ob eine Handoperation durch postoperative dystrophische Symptome kompliziert werden wird oder nicht

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From the Surgical Department of the Maria Hospital Helsinki
(Head Professor P I Tuovinen)

CAUDAL, EPIDURAL ADMINISTRATION OF ANAESTHETICS AND CORTICOIDS IN THE TREATMENT OF LOW BACK PAIN

By

RALF LINDHOLM and PENTTI SALENIUS

A high incidence of back disorders among the population and a high total cost of treatment have recently been reckoned (6 11) The causal diagnosis often remains obscure in spite of accurate clinical and radio logical investigation (8) Treatment must frequently aim only at symptomatic cure and should be conservative at the beginning except in cases of massive root involvement Secondary surgery should be resorted to in cases of chronic disability and if conservative measures have failed (1) There has been a tendency to increase the body of con servative procedures

The use of the caudal approach to the epidural space has been established as a safe and advantageous method for use both in opera tive specialities and in therapeutics (3 4 19) The strong anti inflam matory properties of the water soluble glucocorticoids gave an impulse to their epidural administration in patients with back pain (5 10 12) Combined treatment with anaesthetics has proved promising (2 7)

PRESENT SERIES

We administered prednisolone[1] and xylocain by the caudal method (9) in 33 out patients with low back pain some of them with symptoms of nerve root compression The aetiologic diagnosis could not be stated with certainty in all cases

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1 Di Adreson F aquosum Organon 25–50 mg
Xylocain Astra 1% 15 cc

RESULTS

The results as regards immediate response usually with relief of pain and myospasticity were favorable in 30 patients We were impressed by the free range of movement of the lumbar spine which had previously been in a state of rigidity from muscle spasm Within 30 minutes after injection most patients treated could bend their back quite easily and painlessly in any direction if they were asked to do so The aggravation of pain caused by a sudden cough reflex which was found in 19 patients could not be felt by 16 and was felt only faintly by 2 immediately after injection We registered the immediate reaction and effect upon the clinical sign of Lasegue in each case So it was found that the positive degree of that test usually decreased in some cases reaching an almost normal state simultaneously with the diminishing of pain At follow up usually from two to at most six months after treatment 25 cures 4 improvements and 4 conditions unaltered were registered (Table 1) No serious complications occurred

TABLE 1

Results of caudal epidural injection of xylocain and prednisolone in 33 patients with low back pain

Probable causal diagnosis	Number	Primary response			Follow up		
		Good	Some	None	Cure	Better	Unaltered
Disc degeneration	13	12	1	–	10	1	2
– and root pressure	14	13	1	–	12	1	1
– and acute strain of lig	5	5	–	–	3	2	–
– and postoper root adhes	1	–	1	–	–		1
	33	30	3	–	25	4	4

SUMMARY

The impression was gained of a simple safe and usually effective addendum to the conservative means of treatment of the low back pain patient

RESUME

On a l'impression d'avoir trouvé un moyen complémentaire simple sûr et généralement efficace au traitement conservateur des malades souffrant de douleurs dans la région lombaire

ZUSAMMENFASSUNG

Der Eindruck einer einfachen sicheren und meist wirksamen Hinzufugung zu den konservativen Behandlungsmoglichkeiten des Patienten mit tiefsitzendem Ruckenschmerz wurde gewonnen

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SPONGE RUBBER PAD IN THE PROSTHESIS IN CASES OF CHRONIC DERMATITIS AND ULCERATION IN THE STUMP

By

GEORG BAKALIM

Among the complications affecting amputation stumps, chronic cyanosis, dermatitis, ulceration and pain due to stasis play an important part. These may render the use of a prosthesis impossible for a long period of time and lead to protracted incapacity.

For a long time prostheses have been constructed so that the proximal sides of the stump are weight supporting, since fibrous structures such as fascia and tendons tolerate pressure. Consequently the distal portion of the stump has no proper function: it is pendent in the prosthesis without the leg being exposed to normal physiological axial load. This leads to osteoporosis, which in itself may cause pain in the stump. Furthermore, when the proximal portion of the stump is firmly enclosed all around by the walls of the prosthesis, stasis and oedema are caused in the distal portion, which becomes cyanotic, discoloured and cold. Thus dermatitis and ulceration result, which often defy treatment.

It goes without saying that the first measure to be taken in such cases is to examine the prosthesis. If the latter is narrow, the untoward effect of the above mentioned factors is particularly marked. In such cases the situation may be improved by adjustment of the prosthesis.

In cases of chronic changes in amputation stumps due to stasis, the method used at the Hospital of the Invalid Foundation has been, since 1957, to furnish the end of the socket with a pad of sponge rubber in order to create pressure against the stump. The intention has not been to make an end bearing socket, which would hardly be possible. The variation in pressure between the stump and the pad caused by walking has a pumping effect, which should favourably influence the circula

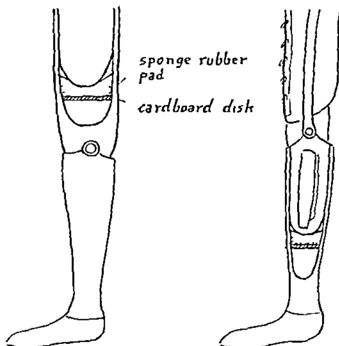


Fig 1

tion in the stump Similar principles of treatement have proved successful in cases of *ulcus cruris*

A sponge rubber pad may readily be fitted into both old and new prostheses at a low cost It can be placed on a horizontal cardboard disk which is the commonest mode of application or directly onto the bottom of the socket of the prosthesis if the stump is sufficiently long (Fig 1) The thickness of the pad varies between 2 and 3 cm and the surface facing the stump is made somewhat concave The adjustment of the pressure between the stump and the pad is of paramount importance To some extent it is facilitated by the elasticity of the sponge rubber If pressure is too heavy both pain and new changes of the skin will soon result If anything of the kind occurs the patient may react by refusing further co operation In addition the possibility of allergic reactions to sponge rubber must be taken into account

In the present study the following data were noted the patient s age and occupation the condition of the stump prior to the use of a sponge rubber pad the colour of the skin the presence of ulceration tenderness swelling and eczema previous performance of sympathectomy the effect of cold winter weather the patient s own opinion on the effect

of the pad and the time that elapsed before any improvement was observable Photographs were taken of all stumps before pads were utilized

The time of observation varied between two and five years

The indications for the use of pads were discolouring of the skin dermatitis and ulceration in the stump

The series consisted of 22 cases (Tables 1 and 2) i e 9 above knee and 13 below knee amputations Twenty of the patients were veterans The patients occupations are indicated in the tables Their ages varied between 35 and 52 years In 6 cases sympathectomy had been performed and in 20 cases a plastic operation of the stump had been performed without any lasting result

In the group consisting of 9 above knee amputations an ulceration healed within four days in one case and in one case an eczema healed within two months Two cases of ulceration and one case of eczema took half a year to heal Three of the patients in this group could not use a pad

In the group consisting of 13 below knee amputations one patient could not use a pad Before the prosthesis was fitted with a pad ulceration was present in 9 cases and both marked discolouring and ulceration were present in 2 cases An ulcer healed in one case in one day in 3 other cases in two four and six weeks respectively In the remaining cases the time required for healing varied between three and twelve months

In one case ulceration recurred when a new prosthesis without a pad had been made but when the pad had been applied again the ulcer healed In another case ulceration recurred after a time of one year and four months in spite of the use of a pad Three patients could not later use a pad although this undoubtedly had brought about healing of their ulcers These patients complained that the pad made the stump too warm and caused irritation but no recurrence of ulceration was observable at the end of the observation time

Of the 9 patients with above knee amputations 6 were satisfied with their pads while of the 13 patients with below knee amputations 12 were satisfied Nobody complained that the pad was cold in the winter On the contrary all patients stated that it warmed the stump just as was to be expected

Thus the result was favourable in 5 cases out of 9 with above knee amputations and in 11 out of 13 cases with below knee amputations It is striking that all these patients had symptoms of long standing which

TABLE 1

No	Occupation	Age in years	Symptoms	Duration of symptoms	Time required for healing	End result
1	Blacksmith	36	Ulceration discolouring	5 years		Could not use a pad
2	Carpenter	42	Ulceration	2 years		Could not use a pad
3	Metal worker	38	Eczema	1 year	4 months	Healed
4	Farmer	43	Eczema discolouring	3 years	2 months	Healed
5	Metal worker	50	Eczema discolouring	5 years		Could not use a pad
6	Industrial worker	40	Ulceration	3 months	4 days	Healed
7	Farmer	37	Ulceration discolouring	2 years	5 months	Healed
8	Unskilled worker	[illegible]	Ulceration discolouring	6 months	6 months	Healed
9	Laboratory assistant	47	Ulceration discolouring	6 months	6 weeks	Healed

TABLE 2

No.	Occupation	Age in years	Symptoms	Duration of symptom	Time required for healing	End result
1	Sailor	39	Ulceration eczema	3 years	5 months	Healed
2	Shopkeeper	35	Ulceration eczema	13 years	12 months	Healed
3	Farmer	44	Ulceration	1 year	3 months	Healed
4	Lumber jack	37	Ulceration	1 year	1 year	Healed
5	Farmer	50	Eczema discolouring	3 months	4 months	Healed
6	Iron plate worker	50	Ulceration	3 years	5 months	Recurrence
7	Electrical worker	44	Ulceration	4 years	5 months	Healed
8	Worker in rattan cane	41	Ulceration	5 years	3 months	Healed
9	Engineer	41	Ulceration	5 years	6 weeks	Healed
10	Farmer	40	Discolouring	2 years	2 weeks	Healed
11	Shoemaker	43	Ulceration	1 year	3 months	Could not use a pad
12	Farmer	40	Eczema discolouring	1 year	3 weeks	Healed
13	Chauffeur	42	Discolouring	4 years	3 weeks	Healed

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From the Mayo Clinic and Mayo Foundation, Rochester, Minnesota

SELECTIVE ANGIOGRAPHY OF COLLATERAL VESSELS IN LIMBS WITH AN EXPERIMENTAL ARTERIOVENOUS FISTULA[1]

By

PATRICK J. VANDERHOEFT and PATRICK J. KELLY

(With the technical assistance of *Glenn Christensen* and *W. Arthur Meeker*)

The present investigations were undertaken in correlation with studies of the changes induced by arteriovenous fistulas in the growth and structure of immature canine bone (9). The overgrowth produced by an arteriovenous fistula appears to be a function of the local changes in hemodynamics. Nonetheless, there is still confusion as to the exact nature of these changes. In vivo angiograms of arteriovenous fistula presented in the literature to date represent the combined image of the arterial and venous vascular trees, which opacify simultaneously because of the fistula. Exceptions are angiograms presented by *Boscher and co-workers* and by *Doumanian*. We have performed selective and bilateral phlebography and arteriography in dogs with a femoral or iliac arteriovenous fistula. We wish to stress a few controversial observations that we made with this method and to point out that the hemodynamics of arteriovenous fistula deserve further consideration.

METHOD

A side-to-side arteriovenous fistula (AVF) was induced between the right superficial femoral vessels in seven puppies 3 to 4 months old and in four adult dogs. One additional puppy had a right iliac AVF. The fistulas were identical, each measuring 1.5 cm. in diameter. The anasto

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Recipient of a NATO Scientific Research Grant, on leave for one year from Hôpital Universitaire Saint Pierre, Université Libre de Bruxelles, Belgium.

mosis was secured with 00000 silk while the vessels were bathed in heparin solution All four branches of the AVF were patent at the end of the procedure The presence of a thrill was observed at weekly intervals With the AVF functioning aorto arteriography and saphenous phlebography were performed at times ranging from 1 to 18 weeks after creation of the AVF Dogs were anesthetized and a catheter was threaded under fluoroscopic control through the left carotid artery to a level in the aorta a little above the iliac bifurcation Then 30 ml of methylglucamine diatrizoate (Renografin) was injected under a pressure of 100 pounds per square inch and a roentgenogram taken 1 to 3 seconds after completion of the injection

Phlebography was performed in both legs simultaneously with the aid of a T shaped catheter inserted in both saphenous veins On four occasions the needles were oriented distally in order to direct the opaque medium toward the deep veins of the foot

Each AVF was then closed surgically by transvenous arteriorrhaphy and aorto arteriography was repeated 15 minutes after closure or 1 to 3 weeks later in the manner described above



Fig 1

Angiogram made 2 seconds after injection of opaque medium into abdominal aorta Arterial tree is visible in both limbs At site of AVF (top arrow) medium has passed into venous tree and has already reached distal end of tibia (double arrow)

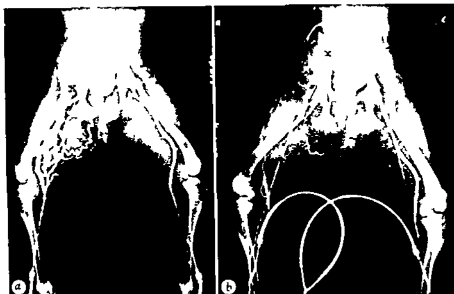


Fig 2

a Bilateral phlebogram made 3 seconds after injection of opaque medium through a T shaped catheter Medium cannot reach site of AVF (X) but bypasses it through deep femoral vein and reaches vena cava practically at same time as on normal side *b* Bilateral phlebogram made 5 seconds after injection of opaque medium with needles oriented distally in animal with 1 week old iliac AVF (X) Again medium cannot reach AVF in femoral veins but is stopped at knee level However it is delivered to the femoral vein at higher levels through collaterals and then is immediately washed out by arterial backflow in a cascade like phenomenon (arrows) Runoff finally occurs through deep circumflex iliac vein abdominal epigastric collateral veins and contralateral pelvic veins

RESULTS

Per Aortic Angiograms With Functioning AVF (Fig 1) —In one of five animals the opaque medium perfusing the veins through the fistula instantaneously filled the saphenous veins down to the ankle (Fig 1) In the other four arterial backflow in the veins stopped at knee level where it looped upward through collateral veins bypassing the AVF

Bilateral Phlebograms With Functioning AVF (Fig 2) —In all of these phlebograms the opaque medium injected near the foot reached the vena cava through collateral veins on the side of the AVF These were fully effective by the end of 1 week (Fig 2b) The opaque medium bypassing the AVF reached the vena cava as soon as that flowing through the normal veins on the left side

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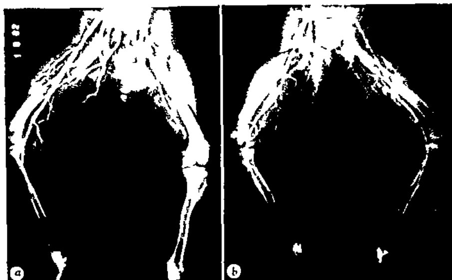


Fig 5

a Aorto arteriogram made 1 minutes after closure of AVF (arrow) showing enormous tortuous arteries

b Similar arteriogram in an adult dog Note increase in length and number of small arteries in thighs

Figure 2b (arrows) demonstrates how opaque medium and venous blood are repeatedly mixed with arterial blood in the femoral vein below the AVF It is delivered there by collateral veins then is washed out by the arterial backflow and loops back through other collateral veins in a cascade like phenomenon

When needles were directed distally 20 ml of opaque medium completely disappeared from the foot on both sides within 4 seconds

Per Aortic Arteriograms After Closure of AVF (Figs 3 4 and 5) — Immediately after repair of the fistula in six of eight animals the arteries on the side of the AVF were hypertrophic This was true of the right iliac artery (whose diameter was twice that of the normal left one) the femoral artery distal to the AVF and the deep femoral and hypogastric arteries bypassing the AVF (Complete filling of the vessels of one limb or the other is an artifact resulting from the orientation of the tip of the catheter) Aortograms made 1 week after those shown in Figures 3 4 and 5 showed that the arteries had shrunk back to normal size and were identical to the left ones

COMMENT

Condition of the Arterial Tree.—Six of the eight bilateral arteriograms made immediately after occlusion of the AVF showed all the arteries of the limb, including the distal fistulized artery itself, to be hypertrophic. The magnitude this hypertrophy can assume has not been fully appreciated in the past (2, 4, 5) except by *Bosher and coworkers* who reported the same findings concerning the arteries that we do. *Robertson and colleagues* found that inflow in dog's limbs with an AVF was more than normal upon acute occlusion of the shunt. They thought that the large collateral arteries accounted for this. By microangiographic examination of femurs that had been subjected to the influence of an AVF, *Kelly and coworkers* observed hypervascularity of the distal and proximal parts of the femur. In our series of eight puppies, two that did not show much hypertrophy of the arteries around the AVF had the weakest response in bone growth. *Holman*, in his excellent description of AVF, has stressed the dilatation of the proximal artery. He demonstrated that the arteries and veins involved in the short circuit of an AVF and the heart itself were dilated somewhat proportionally to the size of the fistula.

Condition of the Venous Tree.—Adequate collateral veins develop around the AVF within a week. We were struck by the fact that edema never developed in one third of the puppies after formation of the AVF. In those in which edema did develop, it always disappeared within a week, as collateral veins formed. This runoff passage was then sufficient to drain the blood from the foot or leg beyond the AVF as fast as was the passage on the normal side. It has been shown that if a side-to-end AVF is created in a limb of a dog wherein experimental venous insufficiency has been produced by deep venous ligation and then the AVF is closed, the venous pressure in the limb diminishes because of the large size of collateral veins the fistula has produced (3).

In serial roentgenograms the opaque medium is seen to remain longer in the vicinity of the AVF than in the corresponding part of the opposite (normal) thigh. This does not represent stasis but active cascade-like recycling as shown in Figure 2b. It is proposed that this be termed "active" rather than "passive" venous congestion or venous stasis.

Two of the eight puppies had typical arterial flow in the veins down to the foot; only one was subjected to phlebography (Fig. 1). The saphenous veins had a definite arterial supply, and red pulsing blood flowed from the right saphenous vein (side of the AVF) toward the

left one through the T shaped catheter used for phlebography More often though this arterial perfusion of the venous tree was arrested at knee level by competent valves This backflow always reaches the knee

SUMMARY AND CONCLUSIONS

In puppies with an induced arteriovenous fistula of the upper part of a limb selective angiography showed the following local circulatory changes (1) arterial backflow in the veins reaching the knee in all cases and the foot in two of eight cases (2) development of sufficient collateral vessels within 1 week to ensure a normal rate of venous re turn from below the knee in the fistulized limb and (3) pronounced hypertrophy of the arterial tree in the fistulized limb of six of eight dogs studied included in this hypertrophy were the fistulized artery proximal and distal to the fistula and the collateral arteries bypassing the fistula the presence of the fistula was necessary for this to occur the hypertrophy disappearing within a week after repair of the fistula

The classic conception of an arteriovenous fistula as a mere shunt is incomplete Such a fistula is a double system consisting of a shunt and of large arterial and venous vessels bypassing this shunt

RÉSUMÉ

Chez de jeunes chiens auxquels il avait été pratique une fistule ar térioveineuse dans la parie superieure d un membre une angiographie sélective a montre les changements suivants de circulation locale (1) reflux artériel dans les veines atteignant le genou dans tous les cas et le pied dans deux sur huit cas (2) developpement de vaisseaux colla teraux suffisants dans l espace d une semaine pour assurer un taux normal de retour veineux depuis la partie inferieure au genou dans le membre fistulisé et (3) hypertrophie prononcee du tronc arteriel dans le membre fistulise chez six des huit chiens étudies touchees par cette hypertrophie se trouvaient l artere fistulisée proximalement et distalement a la fistule et les arteres collatérales traversant la fistule la presence de la fistule etait necessaire pour provoquer cet etat L hy pertrophie disparut dans l espace d une semaine apres la reparation de la fistule

La conception classique d une fistule arterioveineuse plutot comme un shunt est incomplete Une telle fistule est un double systeme con sistant en un shunt et un large passage des vaisseaux arteriels et vei neux par ce shunt

ZUSAMMENFASSUNG

Bei Welpen mit einer im oberen Anteil der Gliedmasse angebrachten arterio venösen Fistel zeigte die selektive Angiographie folgende ortliche Kreislaufsveränderungen (1) Arteriellen Rückfluss in die Venen der das Knie in allen und den Fuss in zwei von acht Fällen erreichte (2) Entwicklung von hinreichend kollateralen Gefässen innerhalb einer Woche um das normale Mass von venösem Ruckfluss von unterhalb des Kniees in die Gliedmasse mit der Fistel zu sichern und (3) ausgesprochene Hypertrophie der arteriellen Verzweigung in der Fistelgliedmasse bei sechs der acht untersuchten Hunde Inbegriffen in diese Hypertrophie war die Arterie mit der Fistel proximal und distal zur Fistel und die Kollateralarterien welche die Fistel umgingen Das Vorhandensein der Fistel war die Vorbedingung für die Entstehung dieses Geschehens indem die Hypertrophie innerhalb einer Woche nach der Reparatur der Fistel verschwandt

Die klassische Auffassung einer arterio venosen Fistel als ein blosser Nebenanschluss ist unvollständig Eine derartige Fistel stellt ein Doppelsystem dar das aus einem Nebenanschluss und grossen arteriellen und venosen Gefässen besteht die diesen Nebenanschluss umgehen

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PSEUDARTHROSIS OF THE SURGICAL NECK OF THE HUMERUS

Two Cases One Bilateral

By

K HARRY SØRENSEN

Fracture of the upper end of the humerus is common in the elderly and usually unites after a few days immobilization followed by active exercises A few fractures through the surgical neck are unstable with poor or no contact between the fractured ends This type of fracture occurs in 4–14 per cent (*Wentworth* 1940 6 of 155 *Einarsson* 1958 12 of 136 *Drapanas et al* 1960 14 of 100) However union is nearly always obtained merely by reduction in some cases open However some surgeons especially in France perform osteosynthesis as a routine procedure either with a Kuntscher type of nail or by a special nail somewhat like the Smith Petersen nail for the femoral neck (*Witte* 1948 *Voss & Hartmann* 1953 *Gandin & Delagrange* 1960) A few have resected the head of the humerus (*Bandmann* 1951) or carried out alloplasty (*Poilleux & Courtois Suffit* 1954) but both methods have given poor results

Pseudarthrosis of the surgical neck is extremely rare so rare that it is not even mentioned in a number of the major recent series (*Wentworth* 1940 155 cases *Madsen* 1949 117 cases *Kothe* 1953 136 cases *Voss & Hartmann* 1953 104 operated cases *Poilleux & Courtois Suffit* 1954 50 cases) or in monographs on pseudarthroses of the long bones (*Verbeek & Dubbelman* 1961) Only in the rare cases with simultaneous total or partial dislocation of the humeral head there might be non union (*Bandmann*)

From the literature I have been able to collect 7 cases of pseudarthrosis of the surgical neck of the humerus

Murphy (1914) described a case in which union was not obtained

despite bone grafting but nailing was needed *Mauclaire* (1920) obtained union in a case of pseudarthrosis by implantation of the shaft into the head of the humerus

In the more recent literature 5 cases are on record *Nissen Lie* (1952) reported 2 cases in women aged 70 and 76 both of whom had been treated primarily by sling One year later pseudarthrosis was found but there was no pain and fairly good function so no treatment was given *Einarsson* (1958) after examined 481 cases of fractures of the upper end of the humerus including 99 involving the surgical neck and greater tuberosity and 136 cases of pure surgical neck fractures 11 of which had been reduced He found only one pseudarthrosis in a 78 year-old woman who had been treated 4 years previously by an axillary pad and sling for 6 weeks despite poor contact at the site of the fracture At follow up the patient suffered pain day and night and was unable to dress or undress The shoulder was tender and swollen There was severe wasting and mobility was considerably restricted there being a maximum range of movement of 50 Moreover there was 6 cm shortening *Drapanas et al* (1960) described among 100 patients 14 with lacking contact at the site of the fracture Four were treated by closed and 6 by open reduction All united Four did not have reduction and 2 developed pseudarthrosis Four years later one of these patients had good mobility no pain and was satisfied with the result The other one had not had reduction because of delirium tremens As good mobility resulted and as the patient had no pain no treatment was instituted One year later there were no complaints but pseudarthrosis

PRESENT CASES

As bilateral pseudarthrosis of the surgical neck has never been published previously the following case history will be reported

Case rec 3/C3 59 A 64-year-old widow After a severe attack of influenza at the age of 26 the patient had been aphonic and asthmatic having bronchitis several attacks of pneumonia and increasing exertional dyspnoea Since the age of 44 therefore she had been receiving disability pension Syphilis had been demonstrated at the age of 27 years and the Wassermann reaction was still positive in the serum but had never been positive in the spinal fluid and neither now nor previously had there been any clinical signs of neurosyphilis From her youth the patient had been suffering from epilepsy with grand mal seizures but had not been investigated or treated for this condition

At the age of 62 the patient fell off a chair in an epileptic fit and sustained frac

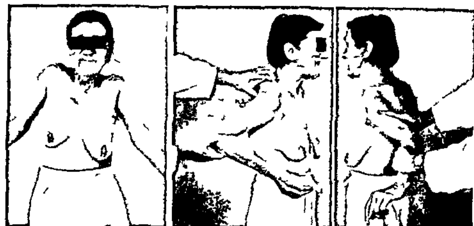


Fig 1

Case 1 From the left

(1) Maximum range of active movement in the right and left shoulder joint 4 and 24 months respectively after the fractures were sustained On the left the fragment of the shaft may be seen as a prominence beneath the skin anteriorly

(2) and (3) show the looseness of the pseudarthroses on the right and left Note the severe wasting of the shoulder muscles



Fig 2

X rays of the left shoulder of Case 1 showing from the left

(1) The fracture immediately after the accident

(2) A loose pseudarthrosis $4\frac{1}{2}$ years later



Fig 3

X rays of the right shoulder of Case 1 showing from the left
(1) The fracture immediately after the accident
(2) The pseudarthrosis 4 months later and
(3) firm union 30 months after the operation (the screw has been removed but there is still a Rush pin through the fracture)

ture of the surgical neck and a Colles fracture on the left After reduction and immobilization in a plaster cast from the knuckles to the shoulder for 7 weeks the wrist fracture had united while the humeral fracture was still loose The patient failed to appear for further treatment

After falling on the stairs at the age of 64 in another epileptic fit the patient sustained a fracture of the right surgical neck and was treated with a sling and axillary pad for 4 weeks followed by active exercises for 4 weeks after which she failed to attend

Four months after the latter fracture the patient was admitted to a medical department totally helpless and in a thoroughly miserable condition I was called and found wobbly pseudarthrosis in the 4 month-old right sided as well as in the 24 month old left sided humeral fracture With difficulty the patient could feed herself with the left hand but was unable to do anything else She was emaciated and anaemic and dyspnoeic upon minor exertion She was fairly demented There was severe generalized muscular wasting most marked in the muscles of the shoulders and upper arms Active movements of the shoulders were exclusively in the pseudarthroses (Fig 1) The general condition did not permit major surgical procedure At operation we found on the right a typical pseudarthrosis with a smooth walled joint cavity filled with synovia and surrounded by a fibrous capsule The fragments were fixed with a Rush pin and a screw The arm was carried in a sling for 4 week

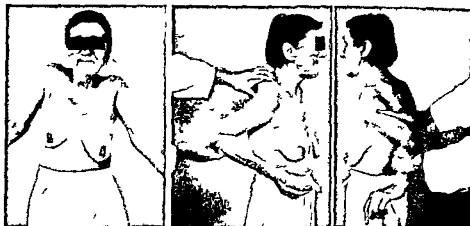


Fig 1

Case 1 From the left

(1) Maximum range of active movement in the right and left shoulder joint 4 and 24 months respectively after the fractures were sustained On the left the fragment of the shaft may be seen as a prominence beneath the skin anteriorly

(2) and (3) show the looseness of the pseudarthroses on the right and left Note the severe wasting of the shoulder muscles



Fig 2

X rays of the left shoulder of Case 1 showing from the left

(1) The fracture immediately after the accident

(2) A loose pseudarthrosis 4½ years later

Through the Directorate of Accident Insurance I found another patient with pseudarthrosis of the surgical neck of the humerus

Directorate of Accid Insur No N 10977/58 A 58 year-old private nurse fell while working in a bathroom and sustained a left sided fracture of the surgical neck with poor contact between the fragments also after reduction After immobilization in a sling for 10 days active exercises were started Six weeks after the accident union was found to be deficient and operation was contemplated but given up because of rheumatoid arthritis which did not involve the shoulder but the wrist and finger joints as well as the left knee It was fairly mild and had been stationary for several years and non disabling Operation was considered several times but when it was offered to the patient 10 months after the accident she declined During the subsequent 2½ years the patient could not work for more than a maximum of 3 days a week At follow up 3 years after the accident she reported that she had been obliged to give up her light nursing work 3 months ago because of the sequelae of the fracture She had pain in the shoulder and arm and reduced strength Active movements took place in the loose pseudarthrosis with severe grating and amounted to forward up and outward up 80 backward 45 internal and external rotation 80/70 With difficulty she could carry her hand to the nape of her neck and to the small of the back There was severe wasting of the shoulder muscles X rays revealed a wide pseudarthrosis with sclerosis of the bone ends (Fig 4) The disability was fixed at 60 per cent

CONCLUSION

Unstable fractures through the surgical neck of the humerus need more attention than other fractures affecting the upper end of the humerus A good contact and effective fixation at the site of the fracture should be established as quickly as possible and union must be confirmed radiologically before the patient is lost sight of If these principles are observed pseudarthrosis seldom develops but if it does it may lead to severe disability

SUMMARY

Pseudarthrosis of the neck of the humerus is extremely rare Only 7 cases seem to be on record Two cases are reported one with bilateral pseudarthrosis resulting from fractures sustained at an interval of 20 months Both patients were severely disabled

RÉSUMÉ

La pseudarthrose du col huméral est extrêmement rare 7 cas seulement ont pu être recueillis dans la littérature Il est rapporté deux cas de cette maladie l'un souffrant de pseudarthrose bilatérale après des

fractures survenues a 20 mois d intervalle Les deux malades etaient fortement invalidés

ZUSAMMENFASSUNG

Pseudarthrosis colli humeri kommt sehr selten vor Man konnte nur 7 Fälle aus der Literatur sammeln 2 Patienten werden besprochen von denen der eine ein doppelseitige pseudarthrose nach Bruchen hatte die mit einem Zwischenraum von 20 Monaten entstanden waren Beide Patienten waren schwer invalidisiert

For the permission to publish Case 2 my thanks are due to C Hagen head of the Directorate of Accident Insurance

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DEGENERATION OF THE INTERVERTEBRAL DISC IN THE CAT

By

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INTRODUCTION

In the three mammals which have been most thoroughly investigated, the dog, cat and man, the intervertebral discs in certain parts of the vertebral column seem particularly liable to pathological changes. Although anatomical factors such as mobility and weight bearing are commonly accepted as the cause of this, the manner in which these factors operate remains largely unknown. This obscurity arises partly from a lack of detailed information about the distribution along the vertebral column of the various types of pathological change; in the absence of comprehensive data it is difficult to know what it is that the anatomical factors have to account for. Most of the information which is available concerns the distribution of dorsal (posterior) protrusions. However, *Hansen* (1952, p. 47) found that in the dog the distribution along the vertebral column of calcification, which is a major form of disc degeneration in this species, was not the same as that of dorsal protrusions; similarly in the cat the distribution of ventral protrusions is different from that of dorsal protrusions (*King & Smith* 1960a, b). This paper reports a comprehensive survey of the macroscopic changes, other than protrusions, which occur in the intervertebral discs of the cat; it will be shown that these changes too have their own particular distribution along the vertebral column. The relationship of these changes to age has also been studied.

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MATERIALS AND METHODS

A total of 110 cats was investigated The first 50 were adults taken at random their ages were unknown except that from the degree of fusion of the epiphyses they were believed to be over 2 years old The second 50 were of known age and represented each year between 2 and 20 some selection was necessary to balance the various ages These were divided into 4 age groups 2 to 6 7 to 10 11 to 14 and 15 to 20 years containing 10 16 11 and 13 cats respectively These 100 cats were the same cats as those investigated for ventral protrusions and dorsal protrusions (*King & Smith*, 1960a b c) There were also 10 other cats juveniles between 1 and 2 years old this material is used below only in the section on age changes All the cats were brought to veterinary surgeons for destruction None was known to be a clinical case of disc protrusion or a similar condition

In every cat each disc was cut transversely and the cut surface was examined except for the coccygeal discs of which none was examined A dissecting microscope was used Most of the cats were fixed in formalin but a few were examined fresh

It is customary to regard some of the senescent changes in the disc as normal or maturation changes and others as pathological or degenerative changes In distinguishing maturation from degeneration we have followed quite closely the criteria which *Hansen* (1952) used for the dog Maturation is essentially fibrous replacement of the nucleus pulposus with perhaps a little chondroid tissue as well A disc was regarded as degenerate if it showed any of the following features 1 Rupture either in the annulus or in a fibrotic nucleus 2 Distinct distortion of the lamellae of the annulus or of the whorls of a fibrous nucleus 3 Generalized separation of the lamellae from each other 4 Extensive conversion into chondroid material 5 Calcification 6 Brown or yellow discoloration

For statistical analysis the chi squared test was used to compare the incidence of degenerations in one region of the vertebral column as a whole with the incidence in another region as a whole The standard error test for proportions was used to compare the incidence at one individual disc with the incidence at the other discs as a whole in the same region of the vertebral column

RESULTS

In 100 adult cats 875 discs (33 6 per cent) out of 2 600 discs showed changes Of these 223 (8 6 per cent) showed maturation and 652 (25 1 per cent) showed degeneration

Maturation

The normal nucleus pulposus of the young cat is slightly flocculent except for a narrow translucent zone round the periphery (Fig 3) This normal cloudiness makes it difficult to distinguish the early stages of maturation in which there is a slight increase in opacity as in Fig 4 Later the whole nucleus becomes completely opaque and definitely loses its gelatinous quality Finally the nucleus is entirely replaced by fibrous whorls as in Fig 5 possibly with a little chondroid material

The distribution along the vertebral column of the discs with maturation is shown in Fig 1 Their incidence in the cervical region (C2 to T1) was about the same as in the region between T10 and S1 There were 46 discs with maturation in the former and 82 in the latter region Since the number of discs in these two regions is different 6 and 11 respectively per cat it is more informative to express the incidence as the mean number of discs with maturation for each disc of the region the mean figures then are 7 7 and 7 5 for these two regions In the region from T1 to T10 (9 discs) however there were 95 discs with maturation or a mean of 10 6 per disc statistically this incidence is significantly higher (P = 0 01) than the incidence in the other two regions In the cervical region and region T1 to T10 no individual disc stood out as having an incidence significantly different from the other discs in its region *However the incidences at T10–11 and at L5–6 and L6–7 were significantly higher* (in all three instances P = 0 02) than the incidence in

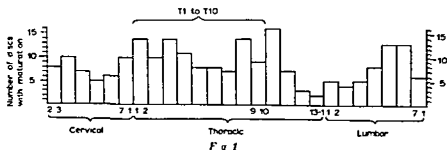


Fig 1

Distribution along the vertebral column of the 223 discs with maturation found in 100 adult cats

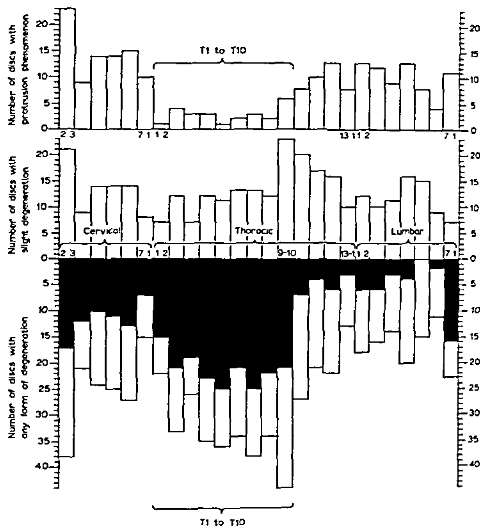


Fig 9

Distribution along the vertebral column of discs with protrusion phenomenon, slight degeneration and all forms of degeneration in the same 100 adult cats as in *Fig* 1. *Top histogram*: distribution of the 219 discs with the "protrusion phenomenon", i.e. discs showing either dorsal protrusion or ventral protrusion or radial slits (no disc being counted twice). *Middle histogram*: distribution of the 333 discs with slight degeneration. *Bottom histogram*: distribution of the 652 discs with any form of degeneration. The black part shows the distribution of the 319 discs with the severe forms of degeneration (*i.e.* advanced degeneration, very advanced degeneration, partial destruction, total destruction or ankylosis). The white part shows slight degenerations only, as in the middle histogram.

the rest of the discs between T10 and S1 it is therefore reasonable to accept the high incidence at L5–6 6–7 as a genuine peak

Degeneration

The distribution along the vertebral column of the 652 degenerate discs is shown in the bottom histogram in Fig 2 and is summarized in Table 1 Degenerate discs were massed in the 9 discs between T1 and T10 Statistically the incidence was significantly higher in the region between T1 and T10 than in the cervical region (P = 0 01) and significantly higher in the cervical than in the region between T10 and S1 (P = 0 001)

TABLE 1

To show the relative incidence of the various degenerations in the three regions of the vertebral column in 100 adult cats

	Slight degeneration No of discs	Advanced degeneration No of discs	Very advanced degeneration No of discs	Partial herniation No of discs	Total herniation No of discs	Ankylosis No of discs	Grand totals
Cervical region C2–T1 (6 discs)	80	35	10	8	13	4	150
Region T1–T10 (9 discs)	110	88	51	33	20	0	302
Region T10 S1 (11 discs)	143	35	13	8	0	1	200
Totals	333	158	74	49	33	5	652

Within the cervical region there was a very high incidence at the first disc C2–3 and a low one at the last one C7–T1 These two incidences were significantly different from the incidence at the other 4 cervical discs together in the former P = 0 01 and in the latter P = 0 02 Throughout the region T1 to T10 the incidence was fairly even except again at the first and the last discs of this region The incidence at these two discs differed significantly from the incidence at the other 7 taken as a whole the incidence at T1–2 being lower (P = 0 01) and that at T9–10 being higher (P = 0 05) In the region from T10–S1 the first disc once again stood out and so did the last but one the incidence at T10–11 was significantly higher and that at L6–7 was significantly lower (in both instances P = 0 05) compared with the other 9 discs taken as a whole

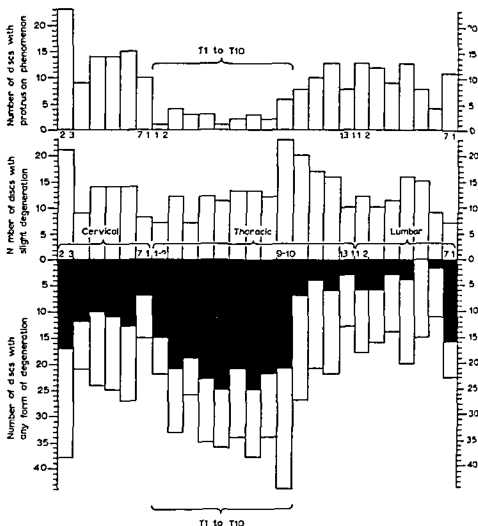


Fig 9

Distribution along the vertebral column of discs with protrusion phenomenon slight degeneration and all forms of degeneration in the same 100 adult cat as in Fig 1 *Top histogram* distribution of the 219 discs with the "protrusion phenomenon" *i e* discs showing either dorsal protrusion or ventral protrusion or radial splits (no disc being counted twice) *Middle histogram* distribution of the 333 discs with slight degeneration *Bottom histogram* distribution of the 652 discs with any form of degeneration The black part shows the distribution of the 319 discs with the severe forms of degeneration (*i e* advanced degeneration very advanced degeneration partial destruction total destruction or ankylosis) The white part shows slight degeneration only as in the middle histogram



Fig 5



Fig 6

Figs 5 and 6

Fig 5 Full maturation of cervical disc of cat Nucleus replaced by fibrous whorls

Fig 6 Slight degeneration in mid lumbar disc of cat Slight distortion of lamellae on right and left sides at about the junction of annulus and fibrous nucleus Scale in mm



Fig 7



Fig 8

Figs 7 and 8

Fig Calcification of whole nucleus in late lumbar disc of cat Calcified material dry crumbly and white

Fig 8 Advanced degeneration in cervical disc of cat Generalized disruption and loosening of lamellae Scale in mm

at the first disc and a tendency for a low one at the last disc the former was significant ($P = 0.05$) but the latter was not In the region T1 to T10 there was a tendency for a low incidence at the first disc T1–2 and there was a high incidence at the last T9–10 the latter being significant ($P = 0.05$) In the region T10 to S1 there was a tendency for a high incidence in the cranial part especially at the first disc T10–11 and a



Fig 9

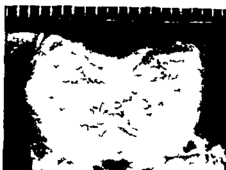


Fig 10

Figs 9 and 10

Fig 9 Very advanced degeneration in mid thoracic disc of cat Original architecture lost Ruptured lamellae everywhere Scale in mm

Fig 10 Partial destruction of lumbar disc of cat Disc reduced to shattered remnants with areas of bone exposed Scale in mm

low incidence at the caudal end especially at L7–S1 but none of these was statistically significant

Calcification accounted for only 14 (4 2 per cent) of the 333 discs with slight degenerations It appeared as a dry white crumbly material and was found in large areas of the annulus or nucleus as in Fig 7 Since no chemical tests were made it is possible that this material was not in fact calcified

2 *Advanced degeneration* The disc showed either generalized changes everywhere or very severe local changes The former consisted firstly of disruption or severe loosening and separation of the lamellae the example in Fig 8 shows some disruption and much separation Secondly the generalized changes sometimes consisted of chondrification the large majority of the disc was then composed of a hard homogeneous *cartilaginous material Some discs combined chondrification* with disruption and separation of lamellae

The localized changes were very severe For example a disc of which about one third had become a disorganized mass (the sort of change affecting the whole of the disc in Fig 9) was classified as advanced degeneration this could affect either the nucleus pulposus or annulus or parts of both but in addition the rest of the disc was almost always at least slightly degenerate A number of severe protrusions were included in this category

A total of 158 discs (24 2 per cent of all degenerate discs) were of

fected by advanced degeneration most of them being in the region between T1 and T10 (see Table 1)

3 *Very advanced degeneration* The disc was absolutely chaotic few or no signs of its original architecture remaining anywhere Many lamellae were ruptured with their stumps sticking up in confusion (Fig 9) Protrusions were sometimes present Seventy four discs (11 3 per cent of all degenerate discs) were in this condition (Table 1) the great majority of them being in the region between T1 and T10

4 *Partial destruction* Small areas of the discs mainly in the central parts had disappeared so that here and there bone was touching bone (Fig 10) The rest of the disc was drastically disrupted the two vertebrae being held together only by weak remnants of disc Sometimes these remnants formed protrusions Of the 49 discs which were so affected (Table 1) the great majority were in the region between T1 and T10

5 *Total destruction* Most of the disc had disappeared so that bone was in contact with bone over large areas Remnants of the disc persisted round the edge but these were totally disorganized sometimes they formed protrusions The two vertebrae were held together only by the most fragile fragments of disc tissue Thirty three discs had reached this stage These were evenly distributed between the cervical region and the region between T1 and T10 (Table 1) Not one was found between T10 and S1

6 *Ankylosis* Ankylosis of two adjacent vertebral epiphyses may be part of the phenomenon of spondylitis rather than of disc degeneration when it occurred the disc was invariably totally destroyed Anyway it was rarely found only 5 discs being so affected All but one were in the neck (Table 1)

The severe degenerations considered as a whole

The distribution along the vertebral column of all the five severe forms of degeneration together (advanced degeneration very advanced degeneration partial destruction total destruction and ankylosis) is shown as the black part of the bottom histogram in Fig 2 A total of 319 discs had these degenerations *i e* 48 9 per cent of all discs with degenerations The majority (60 2 per cent or a mean of 21 3 per disc) were massed in the region between T1 and T10 Most of the rest were in the cervical region (a mean of 11 7 per disc) the region between T10 and S1 being relatively lightly affected (a mean of 5 2 per disc) Stati

stically the difference in incidence between the region T1 to T10 and the cervical region and between the cervical region and the region between T10 and S1 was highly significant (in both instances P = 0.001). Particularly striking was the abruptness of the rise in incidence at the cranial end of the region T1 to T10 and of the fall at the caudal end of it.

Within the cervical region the incidence tended to be high at the first disc and low at the last one but these differences were not significant. Within the region T1 to T10 the incidence was relatively low at the first disc but not significantly so and thereafter was consistently high. Within the region T10 to S1 the last disc stood out with a remarkably high incidence (P = 0.01).

Chondrification

This change was observed in discs which were classified as slightly or severely degenerate. It has not been classed as a separate entity for the reason that chondroid tissue cannot reliably be distinguished from fibrotic tissue with the naked eye. Nevertheless, the tissue identified macroscopically as chondroid was found histologically to consist mainly of dense fibro-cartilage. Although this figure is almost certainly too low, 123 discs (18.9 per cent of all degenerate discs) were recorded as showing chondrification. The great majority of these (80.5 per cent) lay in the region T1 to T10; there were very few in the cervical region (4.1 per cent) and rather more in the region T10 to S1 (15.4 per cent).

Discolouration

Sixty-seven discs had dark red or dark brown discolourations which were either focal or widespread. 43 of these discs also had severe degeneration or protrusions, but only in 3 were these protrusions perforated. A light yellow discolouration, bright and distinct, affected 2[illegible] discs; nearly half of these discs showed only maturation or slight degeneration.

Relative severity of degenerations in the dorsal and ventral parts of the disc

No evidence was found that any of the general degenerations described above affected the dorsal more than the ventral regions of the disc.

Relationship between changes in the discs and age

In the 60 cats of known age the earliest changes to be found were in 2 of the 10 juvenile cats between 1 and 2 years of age. One of these cats had one disc showing maturation, the other had a single disc showing slight degeneration, the nucleus being completely fibrotic and having a large area of dark brown discolouration. Both of these discs were in the region T1 to T10.

The cats in the age groups of 2 to 6 years old and 7 to 10 years old showed a tendency for a progressive increase with age in the incidence of maturation and degeneration, but these changes were only slight in degree, so that in the 7 to 10 group 88 per cent of the discs were still normal while only about 7 per cent were degenerate and 5 per cent showed maturation.

In the next age group, 11 to 14 years old, there was a sharp acceleration in maturation and degeneration. Only about 50 per cent of the discs were still normal and about 30 per cent were degenerate. This acceleration continued still further in the senile group. By this time only 23 per cent of the discs were still normal, and a greater number than this (38 per cent) were affected by severe degenerations; over half the discs (61 per cent) had suffered some degree of degeneration. Nevertheless, even in this senile group every cat had one or several discs which apparently were still perfectly normal; even in the region T1 to T10 apparently normal discs were found sporadically interrupting sequences of grossly degenerate discs.

These changes occurred much more rapidly in the 9 discs between T1 and T10 than in the other two regions. The three regions changed at much the same rate up to and including the 2 to 6 year group (Table 2). But after that the discs in the region T1 to T10 began to change faster than those in cervical region and the region between T10 and S1; the latter two regions continued at roughly similar rates. Thus in the 7 to 10 years group about 80 per cent of the discs in the region T1 to T10 were normal and 5 per cent were severely degenerate; in the other two regions about 90 per cent were normal and only 1 per cent severely degenerate. In the 11 to 14 years group only 36 per cent of the discs in the region T1 to T10 were normal and 24 per cent were severely degenerate; in the other two regions about 60 per cent were normal and only about 7 per cent were severely degenerate. In the senile group 15 to 20 years old only 11 per cent of discs in the region T1 to T10 were still normal and 64 per cent were severely degenerate. The other two

TABLE 2

To show the percentage of normal, mature, slightly degenerate, severely degenerate (all five forms together) discs in the three regions of the vertebral column in the 60 cats of known age

	Cervical region C2 to T1				Region T1 to T10				Region T10 to S1			
	Normal discs	Mature discs	Discs with slight degeneration %	Discs with severe degeneration %	Normal discs %	Mature discs %	Discs with slight degeneration %	Discs with severe degeneration %	Normal discs	Mature discs	Discs with slight degeneration	Discs with severe degeneration
10 Juvenile cats (1–2 years old)	100				97.8	1.1	1.1		100			
10 Young cats (2–6 years old)	96.7		3.3		95.5	1.1	2.2	1.1	89.1		10.9	
16 Early middle aged cats (7–10 years old)	89.5	4.2	6.3	1.0	79.9	11.8	3.5	4.8	93.8	1.1	4.0	1.1
11 Late middle aged cats (11–14 years old)	59.1	18.2	16.6	6.1	36.4	18.2	21.2	24.2	60.3	18.2	14.9	6.6
13 Senile cats (15–20 years old)	24.4	1	28	42.3	11.1	11.1	13.7	64.1	32.8	2[illegible]	28.7	13.1

regions had now parted company through a sudden acceleration of degeneration in the cervical region in which only about one quarter of the discs were still normal and nearly half (42 per cent) were severely degenerate; in contrast to this, in the region between T10 and S1 one third of the discs were still normal and only 13 per cent were severely degenerate.

The regular progression of these changes was interrupted at one point, i.e. in the region T10 to S1 of the young cats (2 to 6 years old). Here Table 2 shows 10.9 per cent degenerate discs, which is more than in the other two regions at this stage. This is due to the fact that, of the total of 14 calcified discs which were observed, 10 occurred in cats of this age group and in this region; no calcified discs were found in cats over 10 years old.

Relationship between degeneration and protrusion

Protrusions (both dorsal and ventral) were found in combination with all the various types of degeneration described above. Thus, of the 333 discs which had undergone slight degeneration 87 (26 per cent) had protrusions; of the 158 discs with advanced degeneration 45 (28 per cent) had protrusions; of the 74 discs with very advanced degeneration 15 (20 per cent) had protrusions; and of the 87 discs with partial destruction, total destruction or ankylosis 29 (33 per cent) had protrusions. The distribution of radial splits among the various stages of degeneration was quite different, since the great majority (37 out of 43) were found in discs which were only slightly degenerate.

Fig. 2 enables the distribution of degenerations along the vertebral column to be compared with that of protrusions. The top histogram is the sum of all dorsal and ventral protrusions and all radial splits (no disc being counted twice); it therefore represents what may be called the "protrusion phenomenon". Altogether 219 discs showed the protrusion phenomenon; these comprised 127 discs with dorsal protrusions, 41 with ventral protrusions, 8 with both dorsal and ventral protrusions and 43 with radial splits. These are the protrusions and radial splits reported earlier (*King & Smith*, 1960a, b).

In the cervical region the distribution of protrusions agreed fairly closely with that of degenerations, especially of slight degenerations, but there was no agreement in the other regions of the vertebral column

DISCUSSION

Degenerative changes

A large variety of degenerations has been seen ranging from slight local ruptures of lamellae to almost complete disintegration of the whole disc These were arbitrarily grouped into six main classes of degeneration slight degeneration advanced degeneration very advanced degeneration partial destruction total destruction of the disc and ankylosis The severest of these degenerations appear to correspond with *Hansen*'s (1959) osteochondrosis vertebrae

From their appearance and relative incidence we believe that these six degenerations are really a sequence of changes which begins locally and mildly within the disc and ends by involving the whole disc even to the point of destruction Some such relationship was suspected by *Hansen* (1959) in his discussion of the cause of osteochondrosis vertebrae though he was unable to rule out the possibility that the degeneration of the disc arose primarily from changes in the vertebrae His difficulty here arises from the destruction of the cartilage plate and the osteolysis and osteosclerosis of the vertebral epiphyseal surface which accompany the very severe degeneration of the disc We suggest that these changes in the cartilage and bone are likely to be secondary to the disintegration of the disc arising from the collision of the adjacent vertebrae

Some of the degenerations observed failed to fit into the concept of this sequence notably chondrification discolouration and calcification Chondrification was the most difficult of these partly because it was hard to distinguish it macroscopically from fibrosis nevertheless it was obviously quite a common change

The dark red and dark brown discolourations looked as though they could have originated from blood *Hansen* (1952 p 54) found similar discolourations in the dog complete with blood pigments (pp 89 111) but only in discs which had completely perforated protrusions or had been surgically fenestrated In our cats however only 3 of the 67 affected discs had perforated protrusions and none had been fenestrated Nevertheless most of these discs were severely disorganized and may have contained damaged granulation tissue Alternatively these discolourations may have come from some unknown pigment (for review see *Hansen* 1952 p 91 and *Hansen* 1959) Of the discs affected with yellow discolourations many were only mildly degenerate or had undergone nothing more drastic than maturation so it is difficult to see where blood could have come from *Hansen* (1952 p 54) saw yellow

grey discolourations in the dog but these were in perforated discs

Calcification or apparent calcification was very rare it was confined to cats younger than 10 years old which suggested that it was not a typical senile change but part of some different process In contrast calcified discs were present in about 50 per cent of dogs of the chondrodystrophoid breeds over 2 years old though rarely in other breeds (*Hansen* 1952 pp 63-65) and in about 75 per cent of humans over 30 years old (*Rathcke* 1932)

Distribution of degenerations along the vertebral column

A conspicuous feature of the distribution of degenerations has been the consistent severity of the changes in the nine discs from T1 to T10 Maturation and degeneration as a whole and particularly the severe forms of degeneration were massed within these nine discs Moreover these changes evidently occurred here much earlier (in the animal s life) and faster than elsewhere in the vertebral column All this justifies the segregation of these nine discs in this species into a clear cut group As for the rest of the vertebral column the cervical region showed more degeneration than the region from T10 to S1 A few individual discs stood out as being either specially susceptible or unsusceptible to degeneration If all forms of degeneration are considered together the first disc of all C2-3 had nearly the highest incidence throughout the whole vertebral column while the last disc of all L7-S1 had an exceptionally high incidence of severe degeneration On the other hand the disc L6-7 was the least susceptible disc throughout the vertebral column this observation is rendered more remarkable by the fact that this disc also had no dorsal protrusions (*King & Smith* 1960b) *Hansen* s (1959) attractive concept of the disc organ visualized all the discs of the vertebral column as a whole organ in which changes take place rather uniformly Our impression of the cat leads us to suggest essentially the opposite principle namely that there is a different susceptibility to degeneration in certain well defined regions of the vertebral column *and perhaps even of certain individual discs*

It is interesting to compare the regional distribution of degeneration of the disc in the cat with the regional distribution of degeneration in other species Apparently the only comparable surveys carried out in other species (excluding surveys of protrusions) are that of calcification in the human disc by *Rathcke* (1932) and calcification in the canine disc by *Hansen* (1952) One notable similarity emerges as in the cat

the thoracic region is much more affected than any other part of the vertebral column Thus by far the greatest incidence of calcification occurred in the nine discs from T2 to T11 in *Rathcke*'s material and in the 13 discs from T1 to L1 in *Hansen*'s It is a fascinating question why should the discs in the thoracic region specially in the part cranial to the 11th thoracic vertebra be so susceptible to degeneration?

No evidence was found that the dorsal part of the disc was any more affected by degeneration than the ventral part unlike the dog (*Hansen* 1952 p 65) and man (according to widely accepted opinions) However *it is possible that histological examination would have disclosed a preferential degeneration in the dorsal annulus of the cat also*

Degeneration and protrusion

In considering the relationship between protrusion and the various classes of degeneration we have taken dorsal and ventral protrusions together as a whole In an earlier paper (*King & Smith*, 1960a) reasons have been given for regarding radial splits as precursors of these protrusions therefore radial splits also have been added to dorsal and ventral protrusions We have called this combination of splits and true protrusions the protrusion phenomenon

Do protrusions arise at any and all stages of degeneration or do they arise at only one stage of degeneration? If protrusions arise spontaneously at all stages of degeneration they should accumulate progressively in the more severe stages of degeneration (assuming that the sequence of degeneration does occur) *i e* there should be a progressively larger proportion of protrusions in the more severe degenerations On the other hand if protrusions arise only for example at the stage of slight degeneration then in each stage of degeneration the proportion of discs with protrusion should remain constant (again assuming the sequence to occur)

The proportion of protrusions actually observed seemed to be approximately *constant in each stage of degeneration* Radial splits on the other hand were nearly confined to discs at the stage of slight degeneration These data fit the hypothesis that the protrusion phenomenon originates mainly at the stage of slight degeneration

The presence of slight degeneration certainly cannot be the only factor which induces protrusion A very large proportion of discs in the region between T1 and T10 must have gone through the stage of slight degeneration but all forms of the protrusion phenomenon were rare in

that region. Similarly the two discs T10–11 and T11–12 had a very high incidence of slight degeneration but a very low incidence of the protrusion phenomenon. Only in the cervical region did the incidence of slight degeneration closely fit the incidence of the protrusion phenomenon.

Age changes

The onset of widespread degeneration in the cat begins essentially in late middle age (in the age group 10 to 14 years). In senile cats between 15 and 20 years old the process is further accelerated. Even the oldest cat, however, always had at least one and usually several discs which were still normal. This was particularly remarkable in the region from T1 to T10 where apparently normal discs were found scattered among sequences of grossly degenerate discs. This again leads us to question the concept of the "disc organ". The onset in late middle age is in contrast to the protrusion phenomenon which in the cat is essentially a feature of senility: dorsal protrusions as well as radial splits and ventral protrusions all occur mainly in cats 14 years old or more (*King & Smith* 1960a, c). In non-chondrodystrophoid breeds of dog *Hansen* (1952, p. 65) found macroscopic degenerations in "isolated" dogs under 7 years old; he further noted that "even in the age group above 7 years they do not amount to a considerable figure", and from this it appears that disc degeneration must be a good deal less common in old dogs (non-chondrodystrophoid) than in old cats.

SUMMARY

1. The macroscopic changes in the intervertebral discs (except coccygeal) of the cat have been surveyed.

2. Maturation (fibrous replacement of the nucleus pulposus) was found in 33 per cent of the discs.

3. Degeneration was found in 25 per cent of the discs.

4. Six main forms of degeneration were distinguished, ranging from slight rupture of lamellae to total destruction of the disc with ankylosis.

5. The appearance and incidence of these forms of degeneration are interpreted to indicate that they constitute a progressive sequence of changes.

6. Maturation and degeneration increased progressively with age but remained uncommon in young cats. In the age group of 11 to 14 years the incidence and severity of degeneration sharply increased. Therefore

in the cat the onset of extensive degeneration is essentially in late middle age in contrast to protrusion which occurs essentially in senility in this species.

7. Degenerations occurred more frequently, more severely and earlier in the nine discs from T1 to T10 than elsewhere in the vertebral column. The region T11 to S1 was the least affected. It is suggested that the discs from T1 to T10 form a distinct group, but no anatomical explanation of this can yet be offered.

8. Protrusions were found equally commonly in combination with all the main forms of degeneration. Radial splits, which are believed to be precursors of protrusions, were virtually confined to discs with only slight degeneration. These relationships suggest that protrusions begin at the stage of slight degeneration.

RÉSUMÉ

1. Une étude a été faite des changements macroscopiques dans les disques intervertébraux (à l'exception des disques caudaux) dans le chat.

2. Dans 35 pour cent des disques une maturation (remplacement fibreux du nucleus pulposus) fut constatée.

3. Dans 25 pour cent des disques une dégénérescence fut constatée.

4. On distingua 6 formes principales de dégénérescence depuis une rupture légère des lamelles jusqu'à la destruction totale des disques accompagnée d'une ankylose.

5. L'aspect et la fréquence de ces formes de dégénérescence indiqueraient, d'après l'interprétation donnée, une série progressive de transformations.

6. La maturation et la dégénérescence augmentèrent par degrés avec l'âge mais ne se manifestèrent que rarement chez les jeunes chats. Dans le groupe âgé de 11 à 14 ans, la fréquence et la gravité de la dégénérescence augmentèrent de façon marquée. Une dégénérescence extensive se manifeste donc surtout sur le déclin de la vie et fait contraste avec la protrusion qui, dans cette espèce, se manifeste surtout dans la sénilité.

7. Une dégénérescence se manifesta plus souvent, plus tôt et avec plus de sévérité dans les 9 disques de T1 à T10 qu'ailleurs dans la colonne vertébrale. La région la moins affectée fut de T11 à S1. Il est proposé que la région de T1 à T10 constitue un groupe uni, bien que l'on ne puisse encore fournir aucune explication d'ordre anatomique.

8. La fréquence des protrusions liées à toutes les formes principales de dégénerescence fut constante. Les fissures radiales, que l'on croit être précurseurs aux protrusions, se limitèrent presqu'entièrement aux seuls disques atteints d'une dégénerescence légère. Ces rapports suggèrent que les protrusions se montrent d'abord à un degré de dégénerescence légère.

ZUSAMMENFASSUNG

1. Es wurde eine Übersicht über die Veränderungen bei den Zwischenwirbelscheiben der Katzen (mit Ausnahme der Schwanzwirbel) durchgeführt.

2. Maturation (fibröse Umbildung des nucleus pulposus) wurde in 33 Prozent der Scheiben gefunden.

3. Degeneration wurde in 25 Prozent der Scheiben gefunden.

4. Es wurden 6 verschiedene Degenerationsformen unterschieden, angefangen von einem leichten Lamellunbruch bis zur vollständigen Zerstörung der Scheibe durch Ankylosis.

5. Das Aussehen und die Häufigkeit dieser Degenerationsformen wird als Hinweis auf eine fortschreitende Folge von Veränderungen angesehen.

6. Maturation und Degeneration nahmen mit fortschreitendem Alter zu, fanden sich jedoch bei jungen Katzen selten. Die Altersgruppe von 11–14 Jahren zeigte einen scharfen Anstieg in der Häufigkeit und in der Schwere der Degeneration. Daraus ergibt sich, dass bei Katzen eine ausgedehnte Degeneration im wesentlichen im späten Mittelalter einsetzt, im Gegensatz zu einer Protrusion, die meistens bei diesen Tieren erst im senilen Alter auftritt.

7. In den neun Scheiben T1–T10 traten Degenerationen häufiger und früher auf und waren schwerwiegender als anderswo in der Wirbelsäule. Die Gegend von T1–T10 war am wenigsten betroffen. Es besteht Grund zur Annahme, dass die Scheiben von T1–T10 eine besondere Gruppe darstellen; eine anatomische Erklärung hierfür kann jedoch bis jetzt nicht in Vorschlag gebracht werden.

8. Protrusionen fanden sich auch ebenso häufig in Verbindung mit allen wesentlichen Degenerationsformen. Radiale Risse, die als Vorläufer von Protrusionen angesehen werden, waren fast ausschliesslich auf Scheiben mit nur leichten Degenerationserscheinungen beschränkt. Diese Zusammenhänge lassen vermuten, dass Protrusionen im Stadium der leichten Degeneration ihren Anfang nehmen.

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ARTERIOVENOUS FISTULA AS A COMPLICATION OF OPERATION FOR PROLAPSED DISC

By

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Perforation of large vessels is a rare complication of operation for prolapsed disc. Most of the reported cases in which perforation of a single vessel occurred ended fatally. When there is simultaneous rupture of an artery and a vein the prognosis is better, even though an arteriovenous fistula with ensuing severe symptoms results. *Horton* in 1961 collected from the literature a series of cases of arteriovenous fistula of this kind and, together with his own two cases, they were thirteen: three fistulae of the aorta and the inferior vena cava (*Kirklin* 1954, *DeBakey et al.* 1958), three of the common iliac artery and the vena cava (*Linton et al.* 1945, *Glass et al.* 1954, *Mack* 1956) and seven fistulae between the common iliac artery and vein (*Holscher* 1948, *Fortune* 1953, *Harbison* 1954, *Smith et al.* 1957).

As Horton points out, it is obvious that it is the present trend, no doubt correct in itself, to remove as much as possible of the degenerated disc tissue and particularly the method recommended by *Dandy* (1944) for instance, i.e. complete or essentially complete removal of the affected discs — which is fortunately probably less frequently employed — which renders such lesions possible. The reports reveal the surprising ease with which rupture of vessels can take place (*Harbison* 1954, *Holscher* 1948).

It has also been shown (*Holscher*, *Leavens* & *Bradford* 1953) in some of the cases described that the instrument has injured the vessel through a defect in the annulus fibrosus. But why was there such a defect? It was probably a result of degeneration or perhaps of the disc prolapse itself. Damage to a blood vessel has occurred even when the operation has been carried out by experienced surgeons and despite the fact that particular care has been taken to avoid this complication.

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the cavity of the disc This observation has also been made in connexion with major vessel damage by some other authors (*Glass et al* 1954 *Seeley et al* 1954 *Harbison*) While preparations were made to explore for safety s sake the disc between the fifth lumbar and first sacral vertebra the anaesthetist reported that the patient s blood pressure was no longer measurable The operation was quickly concluded and it was possible only by massive and rapid blood transfusions to raise the blood pressure again When the patient was turned over we found that the whole left lower extremity was cyanotic as far as to the inguinal fold and the gluteal region but the arterial pulsations of the lower extremities were symmetrical We also found that the left foam latex cushion had been placed too medially to judge from pressure marks clearly observable on the skin (Fig 1b) Preparations were now made for an abdominal exploration but when the leg had been kept elevated for about half an hour with the aid of cushions the cyanosis gradually disappeared and remained very mild after the leg had been placed in a horizontal position The blood pressure remained satisfactory and on waking the patient did not report any pain in the abdomen or pelvis nor did palpation reveal any tenderness resistance tension or other deviation from the normal Recovery was uneventful the symptoms of sciatica disappeared and on the first postoperative day the leg was already warm normal in colour and without oedema The abdominal and pelvic organs functioned normally The patient was discharged on the tenth postoperative day after she had been ambulant for some days During her stay in hospital the patient had a cough Radiographs revealed slight enlargement of the heart and insignificant pulmonary stasis (no preoperative chest radiograms had been made) Electrocardiography revealed nothing abnormal

After discharge from the hospital there was rapid development of cardiac insufficiency and pulmonary embolism the left lower extremity became swollen the patient s weight increased and her condition remained poor despite intensive medication for the cardiac insufficiency and the pulmonary embolism Six weeks after the operation for disc prolapse the patient was seen again by the surgeon and only then was it recognized that her condition was caused by an arteriovenous fistula obviously between the left common iliac artery and vein She had pronounced cardiac insufficiency with ascites and pulmonary stasis (Fig 2a) The left leg and thigh were highly oedematous above and below the knee the circumference of the extremity was 6 cm larger than that of the right extremity A pronounced murmuring thrill was audible and




Fig. 2.
A. Thorax radiogram ten weeks after operation for prolapsed disc. B. Two weeks after repair of fistula. C. Four weeks after repair of fistula.

A




B




C



Fig 3
In an arteriogram made through the right femoral artery the left common iliac artery is not demonstrable



Fig 4
A Schematic representation of the site of the fistula The right common iliac artery curves over the highly dilated left common iliac vein
B Schematic representation of the same area at the end of the operation The left common iliac vein is ligated In the artery the fistulous area has been substituted with a prosthesis

perceptible in the lower abdomen caudally of the umbilicus and to the left Arteriography showed caudally of the umbilicus and to the left Arteriography showed a fistula between the left common iliac artery and vein (Fig 3)

2½ months after the operation for disc prolapse operation for the repair of the fistula was carried out Through a long left paramedian



Fig. 5
Photography after closure of the fistula and suture of the prosthesis

transrectal incision the large retroperineal vessels were exposed. Near the bifurcation a fistula was found between the left common iliac artery and vein. The inferior vena cava and both common iliac arteries and veins were closed with Pott's clamps and a weak heparin solution was injected into the distal arteries. Efforts were then made to free the highly distended common iliac vein. It was so firmly adherent, however, to the underlying tissues that dissection was impossible. When the fistula was opened it was observed that the venous dilatation contained a thrombous mass and that the wall of the vein was degenerated and rather brittle. The common iliac vein was ligated on both sides of the dilatation. The opening in the artery was so large that direct closure of it as well as arteriorraphy after resection of the *fistulous* area was considered too risky; the fistulous segment was resected (Fig. 4) and the loss was compensated with a Teflon prosthesis about 2 cm long (Fig. 5). No conclusions as to the mechanism of origin of the fistula could be made.

Recovery was uneventful. Distal arterial pulsations were easily felt *immediately after the operation*. The cardiac insufficiency was rapidly overcome (Figs. 2b, c). Upon ambulation on the ninth postoperative day the leg no longer swelled to any noticeable degree and no supporting bandage has since been necessary. The condition of the extremity and back has been good ever since (3½ months after the operation).

CONCLUSIONS

This case constitutes a reminder of the difficulty and even danger of an operation for prolapsed disc. The patient's position on the operating table must be carefully observed. Compression of large vessels must be avoided. Infinite care must be observed in the evacuation and palpation of the disc. Although all degenerated tissue must as far as possible be removed, this must be done with the utmost caution. To use forceps to remove tissue from the bottom of the disc cavity is certainly a most dangerous procedure, particularly in view of the possibility of a defect of the annulus. In operations for disc prolapse one must be prepared for quick and massive blood transfusions.

The cause of such an easily occurring rupture of a vessel must be pathological weakness of the vascular wall, since when these vessels are otherwise manipulated they do not appear to rupture so easily, even in the case here described. It is possible that prolapse of the disc also takes place in a ventral direction and this, or osteochondrous prominences of the vertebral edges, may cause degeneration or erosion of the vascular wall. There is no doubt that the patient's prone position and the compression of the vessels against the spine facilitate the occurrence of a lesion. It has been established that when a large vessel has perforated and if the haemorrhage and ensuing symptoms do not spontaneously cease at once, immediate exploration and operation are the only means of saving the patient's life. As a rule there is no urgency about the repair of an arteriovenous fistula; in fact the development of a collateral circulation is an advantage since ligation of vessels may prove necessary. Cardiac insufficiency and pulmonary embolism, however, necessitate quick closure of the fistula.

SUMMARY

A fistula between the common iliac artery and vein arising at an *operation for prolapse of the disc between the fourth and fifth lumbar* vertebrae is described. Severe, rapidly exacerbating symptoms necessitated closure of the fistula 2½ months later. The operation was successful.

At operation for prolapse of a disc the possibility of this rare but serious and easily occurring complication should always be borne in mind.

RESUME

Description d une fistule entre l artere et la veine iliaques survenue a la suite de l operation d une hernie discale entre la 4ème et la 5ème vertèbre lombaire Des symptomes graves devenus rapidement exacerbants necessiterent la fermeture de la fistule 2 mois et demi plus tard L operation reussit

Dans l opération de la hernie discale il convient d avoir a la memoire la possibilite de cette complication rare mais grave qui peut toujours se produire

ZUSAMMENFASSUNG

Eine Fistel zwischen der A iliaca communis und Vene die anlässlich der Operation eines Scheibenprolapses zwischen 4 und 5 Lendenwirbel entstand wird beschrieben Schwere rasch sich steigernde Symptome machten eine Schliessung der Fistel 2½ Monate später nötig Die Operation war erfolgreich

Bei der Operation wegen Scheibenprolaps sollte immer an die Moglichkeit dieser seltenen aber ernsthafter und leicht entstehenden Komplikation gedacht werden

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POST-TRAUMATIC LESIONS OF THE LUNATE BONE

By

INGER BROLIN

Of injuries to the wrist bones, navicular fractures are the most common, followed by lesions of the lunate bone (*Bavendam, Cave, Jensen, Kappis*). The pathologic change that is variously termed lunatomalacia, Kienböck's disease, post-traumatic malacia, chronic osteitis and aseptic necrosis has been the subject of comprehensive studies since the end of the last century, when anatomists described such lesions under the designations lunatum partitum, bipartitum, epilunatum, etc.

Of the theories propounded regarding the mechanism of origin, four different categories may be distinguished. (1) *Axhausen's* theory differs essentially from the others in that he discounts the notion of a traumatic etiology and believes the cause to lie in an aseptic embolus of unknown origin. All other investigators attach major or minor significance to traumata.—(2) *Kienböck*, who in 1910 described in detail the symptomatology and roentgenologic picture of lunatomalacia, attributed the condition to ruptured ligament and vascular injuries attendant upon dorsal subluxation of the semilunar bone. The vascular disturbance in his opinion gave rise to malacia of the bone, and subsequent traumata resulted in compression and fragmentation. Opponents of Kienböck's theory have asserted that dislocation of the lunate bone is never followed by malacia (*Hultén* and others) and that ligament ruptures are not demonstrable at microscopic examination of malacia (*Fabricius-Møller, Cordes*).—(3) *Müller* in 1920 advanced a theory according to which minor traumata lead to pathologic processes of obscure character. This theory was based on the fact that the disease most commonly affects the right hands of manual workers. Although a few other investigators have subscribed to Müller's theory (*Gocke, Esau* and others), the majority believe that a compression fracture is primary.—(4) The fracture theory, fortified by the results of microscopic

examinations (*Cordes*) which show that in the majority of relatively fresh cases a fissure is discernible, generally running parallel with the proximal articular surface. These cases exhibit hematomas—indication that the fractures have occurred in living bone. In the course of time these hematomas are resolved and the picture is one of necrotic areas gradually replaced by fibrous tissue. Since this tissue is never observed to contain hematomas or necroses the lesion has manifestly been produced by a single trauma or, possibly, by repeated traumata over a very short period. Traumata repeated at longer intervals should logically give rise to every gradation between fresh hematomas and necroses but in no case did *Cordes* observe any such lesions.—Opponents of the fracture theory point out that roentgen examinations have failed to reveal any malacia following fresh fractures of healthy bone. *Ståhl*, however, in a series of 184 cases, observed four fresh compression fractures which had resulted in typical malacia.

Some authorities contend that the etiology may vary from case to case, but *Persson* has emphasized the absence of any roentgenologic or histologic difference between verified post-traumatic malacia and malacia with no history of trauma. The condition, in his opinion, is a distinct pathologic entity.

The fracture theory is the oldest and most widely accepted of the four. It is supported, moreover, by *Hultén's* investigations, which demonstrate a statistically significant preponderance of minus variants. In *Hultén's* study non-variants are those cases in which the distal articular surfaces of the radius and the ulna show no difference in level. In plus variants the ulna is longer than the radius, and in minus variants shorter.— *Hultén* observed that in plus variants cystic changes may occur in the ulnar portion of the lunate bone. The cause, in his view, is a maximal load on a punctate area.

Kostler, assuming *Hultén's* hypothesis, attributes the cyst formation to repeated traumata. He has found that the cysts may occur in non-variants too and is therefore unable to accept ulnar compression of the semilunar bone as a likely cause. The etiologic factor, he believes, is a damaged disc giving rise to an intra-articular lesion of the lunate.

Kappis, in microscopic studies of post-traumatic navicular cysts, noted that they were filled with fibrous tissue—the remains of necrotic tissue or resolved fracture hematomas. In his opinion small necroses develop at the surface of all compression fractures. Compression of the cancellous bone, moreover, may result in the formation of small bone fragments that are completely isolated by fractures and hence undergo

necrosis If fractures run in the proximity of nutrient foramina they may *lead to vascular lesions with the attendant danger of central necrosis* Even intraosseous hematomas may give rise to cystic cavities *Kappis* considers that although the mechanism of origin may vary somewhat trauma is the eliciting factor

MATERIAL

Of a series of approximately 5 000 wrists roentgenologically examined since 1951 pathologic changes of the semilunar bone were observed in a total of 158 patients Ninety of these returned for follow up examinations comprising conventional roentgenograms of both wrists and tomograms of the injured hands For tomographic examination (Polytome Massiot) a polycycloid movement with sections at intervals of 2 mm was applied The examination generally included both frontal and lateral projections

TABLE 1

Distribution of the Series by Side and Sex

		Males			Females			Total
		Right	Left		Right	Left		
I	Sclerosis	1	1	(2)	–	1	(1)	3
II	Dislocations	6	2	(8)	–	–	–	8
III	Avulsion of compact fragments	3	1	(4)	–	1	(1)	5
IV	Structural changes without compression	23	23	(46)	20	26	(46)	92
V	Structural changes with compression	23	11	(34)	10	6	(16)	50
							Total	158

Males 94 cases Females 64 cases Right hand 86 Left hand 72

The distribution of the series is shown in Table 1 The first three groups with readily definable changes comprise a total of 16 cases The remaining 142 cases form two groups In group IV structural changes of the spongy bone are present alone while in group V they are associated with lunate deformation due to compression In order to determine whether compression was present the index reported by *Ståhl* was applied

$$\text{Index} = \frac{\text{Vertical height}}{\text{Horizontal diameter}} \times 100$$

The height was determined by measuring the distance between the proximal and distal articular surfaces on the lateral projection and the horizontal diameter by measuring the greatest dorso-volar diameter perpendicular to the vertical height. The measurements were made with an accuracy of 1 mm. Control measurements in 100 healthy wrists showed an index range of 50–70 (median 58). On this basis quotients of less than 50 were considered tantamount to compression. Such cases were assigned to group V consisting of fresh compression fractures and malacia. Group IV is composed largely of lesions designated as cysts.

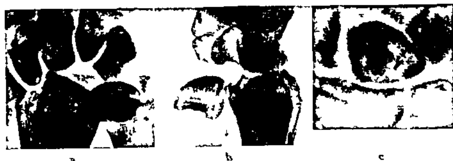
TABLE 2
Age Distribution of the Series

Age	Male	Female
11–20	4	4
21–30	17	11
31–40	16	9
41–50	29	10
51–60	17	11
61–70	9	12
71–80	2	5
81–90	–	1
91–100	–	1

From the age distribution (Table 2) it will be seen that the majority of the patients were of physically active age. In terms of age distribution the malacia and the cyst groups do not differ markedly from the total series. Eighty seven per cent of the males were manual workers.

I. *Sclerosis*

Each of two patients exhibited a central island of compact tissue. One of them was followed up and showed an unchanged picture after five years. The third patient in this group had a well delineated area of subchondral sclerosis in the distal part of the bone and a similar lesion was observed in the contralateral hand. In this patient too the sclerosis was unchanged at follow up. These changes probably constituted developmental defects.



a b c

Fig 1

Severe dislocation of lunate bone (a) Frontal and (b) lateral projection (c) Tomograph in frontal projection 1½ years after the trauma



a b c

Fig 2

Perilunar dislocation associated with navicular fracture (a) Frontal and (b) lateral projection (c) Follow up 11 months after the trauma

II *Dislocations*

Lunate dislocations assume two forms (1) Direct volar displacement in relation to both the radius and ulna and the other carpal bones and (2) no direct displacement of the lunate relative to the radius and ulna but dorsal luxation of the other carpal bones The latter form is known as perilunar dislocation Lunate dislocations are invariably associated with fractures of adjacent bones The present series includes three cases of direct luxation (Fig 1) and three of perilunar dislocation (Fig 2) Each of these patients underwent roentgen examination at the time of the trauma then immediate reduction of the dislocation In none of the three followed up cases did structural changes develop in the semilunar bone (Fig 1)

There were also two inveterate cases with a history of trauma about



Fig 3

Volar avulsion of compact fragment (a) Lateral projection at time of trauma (b) Follow up 10 years later (c) Tomography in lateral projection shows cortical defect but no structural changes

twenty years before roentgen examination In both cases the lunate bone still showed volar dislocation and like the other carpal bones and the distal portion of the radius and ulna deformation Tomographic examination revealed partial sclerosis of the lunate Although its dorsal border was lower than normal no fragmentation or cystic rarefaction as in malacia was observed

III *Avulsed Compact Fragments*

Only in five cases was avulsion of lunate cortical fragments noted Avulsion had occurred from the volar aspect in three and from the dorsal aspect in two In the first mentioned three the cortical defects were clearly discernible (Fig 3) At follow up 5 10 years later both the defects and the fragments were still evident Thus there was no tendency to resolution of the fragments which had become rounded and well defined Neither in these three cases nor in the two with dorsal fragments were structural changes detectable in the lunate bone

IV *Structural Changes in Non compressed Lunate Bones*

This group comprising 92 cases consists largely of cysts However tomographic examination shows that the structural changes which on conventional roentgenograms are regarded as cystic correspond to defects and the fragments were still evident Thus there was no tendency predilection one situated proximally towards the radial aspect the other dorso-proximally towards the ulnar aspect (Figs 5 and 6)

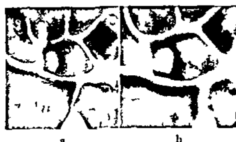


Fig 4

(a) Frontal projection showing lunate "cysts" (b) Tomographs of same case reveals deep defect towards radial aspect of the lunate

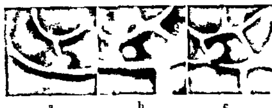


Fig 5

Tomographs in frontal projection of lunate cysts situated towards the radial aspect

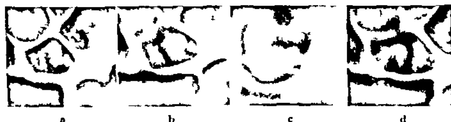


Fig 6

Tomographs of (a) and (b) cavities in ulnar portion and (c) dorsal cavity (d) Large irregular "cyst" with proximal defect in the lunate

In this group all gradations from shallow depressions to rounded cavities associated with fairly wide cortical defects were observed on the tomograms The cavities had smooth walls but were usually irregular in shape (Fig 6 d) In addition to those located near the radial and ulnar aspects others were situated beneath the dorsal and the volar surfaces (Fig 6 c) Common to them all however was a proximal localization in the lunate bone Large "cystic formations sometimes ex-



Fig 7

Tomography in lateral projection of different cases with subcortical "cysts" and cortical defects at sites of nutrient foramina

tended some distance distally but the cortical defects were situated proximally (Fig 6 d)

Besides these more or less deep cavities another form of cystic rarefaction was noted consisting of cystic areas a few millimeters beneath the compact bone From the cysts narrow ducts—possibly corresponding to nutrient foramina—passed through the cortex to the bone surface (Fig 7) Although the cysts were as a rule solitary some measure of variability was apparent and in extreme cases the entire bone was pervaded with cystoid cavities In no case however was there any deformation of the bone contour

Eight patients had bilateral lunate cysts and 11 showed cystic involvement of other carpal bones as well In all save one of the followed up cases (48 patients) the lesions retained their shape and size during the observation period though in most cases the adjacent bone tissue became more sclerotic The single exception was a patient who at roentgen examination in 1957 showed only a cystic rarefaction A follow up in 1961 revealed compression and fragmentation of the semilunar bone as in malacia

One patient underwent surgery the operation disclosing a spherical cavity containing a yellowish gelatinous fluid under pressure A fissure extended through the cortex to the cartilage of the navicular aspect Histopathologic examination showed cell deficient fibrous tissue but no inflammatory cell infiltration and no myxoma like tissue

A *Structural Changes in Compressed Lunate Bones*

This group includes both fresh compression fractures and pronounced malacia" as well as cases intermediate between the two Tomography of the lunate showed bone densities as well as cystic rarefaction in the same bone The compression had served to increase the dorso-volar diameter while the radio ulnar diameter was unchanged The

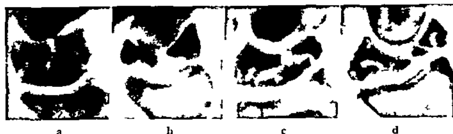


Fig 8

Tomographs in lateral projection of different malacia cases showing various degrees of fragmentation and compression



Fig 9

Different cases with compression of the proximal portion of the lunate showing fractures parallel with the articular surface

degree of compression varied greatly as did the fragmentation (Fig 8) No correlation existed between the degree of compression fragmentation and the age of the lesion

A fracture which divided the lunate bone into volar and dorsal fragments was noted in 27 cases (Fig 8) In ten cases only the proximal part of the bone was compressed and here a fracture ran parallel with the proximal articular surface (Fig 9)

Two patients had fresh compression fractures due to severe trauma sustained in accidents They were treated with fixation and the fractures healed with slight deformation of the bone but no malacia In another four cases the initial roentgen examination disclosed slight compression but in view of the relatively mild trauma prolonged fixation was not considered necessary Follow up roentgenograms showed in all four a typical malacia picture (Fig 10) In a further six of 26 cases followed up more than one year after the first roentgen examination the compression had increased

The minus variant described by *Hulten* (see page 168) was noted in 23 cases (47 per cent) the non variant in 11 (22 per cent) and the plus



Fig 10

(a) Compression fracture in radial portion of lunate bone due to mild trauma (b) Four months later the compression has increased (c) Two years after the trauma typical malacia picture

variant in 15 (31 per cent) Thus there was a definite preponderance of minus variants The three categories however showed no significant differences in the degree of compression The compression index averaged 35 for minus variants 34 for non variants and 32 for plus variants

The lesions were twice as common on the right as on the left side Only one of the patients with left sided lunate malacia was sinistromanual One patient had bilateral lesions The group consisted of 34 males and 16 females—a sex distribution which doubtless reflects the occupational disparity

Anatomic and Mechanical Conditions

Before proceeding to discuss the mechanism of origin of malacia and cysts I will first recapitulate briefly the anatomic and mechanical conditions to which the lunate bone is subject Of the dorsal and volar groups of ligaments which extend from the radius and ulna to the carpal bones only a few fibers are attached to the lunate bone It is for this reason that avulsion of lunate fragments is rarely observed Interosseous ligaments however unite the lunate with other carpal bones though only those connecting the lunate and navicular bones permit any major degree of motion With volar flexion the navicular rotates 90 degrees whereas the semilunar bone moves only 30 degrees On dorsal flexion the navicular does not pass the long axis of the radius while the lunate rotates 10 15 degrees dorsally (Fig 11) A certain screw like movement between the navicular and lunate bones also accompanies radial flexion With ulnar flexion the lunate glides on the articular surface of the radius its radial portion passing the ridge which divides that surface into two parts corresponding to the articular surfaces of the navicular and lunate in mid position (Fig 12



Fig 11
Motions of lunate and other carpal bones on (a) volar flexion and (c) dorsiflexion (b) Mid position



Fig 12
Motions of lunate and other carpal bones on (a) radial flexion and (c) ulnar flexion (b) Mid position

Trauma sustained via the capitate bone will due to the semilunar shape of the lunate be propagated through the latter's center Since the radial and ulnar articular surfaces are oblique lines of force from other carpal bones converge on the lunate (Fig 13) Thus the lunate is subject to a greater pressure than any of the other wrist bones no matter what the position of the hand may be (*Cordes*) The lunate articulates proximally with both the radius and the ulna *Hullen* has shown that with compression the distance between the lunate and the ulna decreases but the distance between the lunate and the radius remains constant The ulnar disc therefore is more resilient than the articular surface of the radius With violence in the long axis of the hand the lunate will be compressed between the carpal bones on one

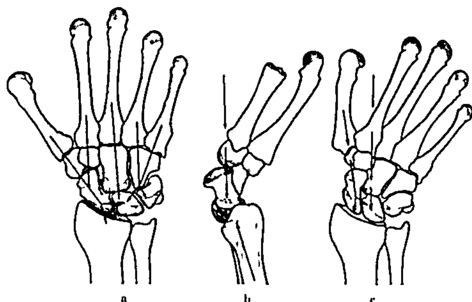


Fig. 13
Schematic representation of the forces acting upon the lunate. (a) Mid position. (b) dorsiflexion. (c) ulnar flexion.

side and the radius and ulna on the other. Because of uneven resistance in the proximal articular surface the load will be greater on the radial than on the ulnar portion of the lunate bone—a circumstance conducive to compression fracture. The uneven load will be accentuated if the ulna is shorter than the radius, as in minus variants (*Hultén*).

The lunate bone has been likened to a cartilaginous capsule enclosing a cancellous central portion. Of all carpal bones the lunate has proportionally the largest cartilage covered area. For this reason it is relatively insensitive, since cartilage itself has no nerve supply and cancellous bone has a lower pain sensibility than periosteum (*Hultén*).

Owing to this discrepancy between cartilage covered and periosteum covered surfaces, moreover, the vascular supply of the lunate is readily damaged. Only on the volar and dorsal aspects of the lunate are there small periosteum covered areas, and here the bone is nourished by a varying number of small vessels—two to four on the volar aspect and one to four on the dorsal (*Cordes, Ståhl*).

Watson Jones has shown that in fractures the initial hyperemia must subside before calcium deposition can take place in new osteogenic tissue. The hyperemia, which is due to the release of acetylcholine, histamine and similar substances into the tissue, ceases after approximately

ten days With poor fixation and with repeated traumata the release of these substances continues the hyperemia persists and decalcification proceeds A crack becomes a cavity a linear fracture a gap fracture

DISCUSSION AND CONCLUSIONS

Malacia

The two principal arguments against the fracture theory have been first the frequent lack of any history of trauma in malacia cases and secondly the fact that fresh compression fractures have not been observed to develop into malacia Only 50 per cent of the patients in this series had any recollection of a specific trauma However it is evident from the aforegoing that by virtue of the enclosed position of the lunate bone very little violence is required to injure it Due to the relative insensitivity of this bone the injury may easily escape detection This accounts for the inability of so many of these patients—most of whom are manual workers and frequently suffer minor injuries—to recall a particular trauma In the acute stage they make light of the injury and are thus exposed to the risk of defective healing

Ståhl has shown that in some cases the development can be followed roentgenologically from compression fracture to malacia The present series includes four such cases (see page 175) The lunate dislocations on the other hand healed without structural changes even though the blood supply must have been seriously affected Even avulsion of cortical bone fragments is likely to be associated with ruptured vessels yet in none of five such cases did lunate malacia develop In this series therefore nothing has emerged to conflict with the fracture theory The cases of fresh compression fractures that healed after fixation (see page 175) lend further support to the assumption that lunate malacia is not malacia in the strict sense but merely a defectively healed compression fracture

Cysts

As regards cystic rarefaction the mechanism of origin as *Kappis* pointed out probably varies though local compression is a feature common to all cases At times the trauma may lead to compression of the elastic cartilage When this cartilage subsequently springs back a cavity containing blood and compressed bone fragments forms beneath it The impaired blood supply precludes normal bone tissue regeneration and the cavity fills with fibrous tissue and fluid In due course

the necrotic area in the cancellous bone becomes larger than the cortical defect.—The fissure through the cortex observed at operation on one of the present cases may have corresponded to the fracture. Local subchondral compression fractures of this type usually involve the radial aspect where the proximal ulnar border of the navicular may be forced against the lunate bone (Fig. 5).

Cystic cavities not situated at the periphery are, as mentioned above, directly connected with nutrient foramina. Injury of the vessel in the cancellous bone gives rise to a hematoma which on resolution leaves behind a cystic cavity. That a fracture would by rupturing vessels lead to central necrosis—as *Kappis* believes—seems unlikely, for avulsion of cortical fragments with vascular damage does not lead to cystic rarefaction, either peripheral or central.

Both malacia and cysts thus appear to be post-traumatic changes in the lunate bone. Malacia represents a defectively healed fracture after compression of the whole or the greater part of the bone. "Cysts" are residual conditions following local compression by an adjacent bone.

SUMMARY

Of 168 roentgenologically observed cases of lunate bone lesions, 90 were subjected to tomographic follow-up examination. The bulk of the total series consisted of "malacia" (50 cases) and "cysts" (92 cases). In no case did lunate dislocation or vascular injuries of other etiology lead to malacia. Typical malacia did develop, however, from fresh compression fractures. The malacia cases represented defectively healed compression fractures, the "cysts" were *residual conditions stemming from local compression*.

RÉSUMÉ

Sur 168 cas de lésions de l'os semi-lunaire constatées radiologiquement, 90 ont été soumis à un réexamen tomographique. La saillie consistait pour la série totale en « malacie » (50 cas) et « kystes » (92 cas). Dans aucun cas la dislocation ou des lésions vasculaires d'une autre étiologie n'étaient cause de la malacie. Une malacie typique s'est néanmoins produite à la suite de fractures fraîches de compression. Les cas de malacie représentent des fractures de compression dont la guérison est défectueuse; les « kystes » étaient de nature résiduelle provenant de compressions locales.

ZUSAMMENFASSUNG

Von 158 rontgenologisch beobachteten Fallen von os lunatum Verletzungen wurden 90 einer tomographischen Nachuntersuchung unterzogen Der Hauptanteil der Gesamtreihe bestand in Malacien (50 Falle) und Cysten (92 Falle) In keinem Falle fuhrte Lunatumluxation oder Gefassverletzungen anderer Ethiologie zur Malacie Typische Malacie entwickelte sich jedoch aus frischen Kompressionsbruchen Die Malacie Falle stellten fehlerhaft geheilte Kompressionsbruche dar Die Cysten waren Restzustande nach ortlichen Kompressionen

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DYSPLASIA EPIPHYSEALIS CAPITIS FEMORIS

A Clinical radiological Syndrome and its Relationship to Legg Calve Perthes Disease

By

JOHANNES MEYER

At the Coastal Hospital Refsnæs and at the Finsen Institute Copenhagen Denmark about 300 cases of Legg Calve Perthes disease have been treated so far

Detailed analysis has shown that these cases do not make up a uniform homogenous group

In addition to the typical syndrome there is at least one well defined group of cases differing from the typical one radiologically as well as clinically—not least in respect to prognosis

Let me first specify what I consider characteristic of the typical Legg Calve Perthes syndrome This brief description will be based mainly on the radiological appearances Of cource the clinical symptoms are of great importance but so uncharacteristic as to be of limited interest in this context

Legg Calve Perthes disease develops in *an epiphysis which previously has appeared completely normal—in shape as well as size*

On this item there is by now general agreement but this has not always been so

In the nineteen twenties and thirties a group of orthopaedic surgeons headed by *Calot* held that the disease always arose in a hip joint which was already the seat of slight congenital subluxation *Calot* made the the sharp statement that "L osteochondrite ou "maladie de Legg ou de Perthes *n existe pas* Il s agissait de *subluxations meconnues*

These views were so severely criticized (*Calvé Perthes Sorrel Waldenstrom* and others) that the orthopaedic surgeons of those times were gradually left with the impression that *Calot* s views were erroneous Since then there has been practically no discussion about this

question and to day it is considered an established fact that the Legg Calvé Perthes disease develops in a hip joint which has previously been completely normal clinically as well as radiologically.

This related to possible *premorbid* changes in Legg Calvé Perthes disease.

As to the development of the disease itself it may be briefly stated that

The first radiological sign of Legg Calvé Perthes disease is—in addition to slight widening of the joint space—*massive uniform condensation* of the bone tissue in the epiphysis which is otherwise normal in shape and size. However, soon the epiphyseal contours become a bit angular and at the same time the epiphysis shrinks a little—but the diffuse uniform condensation remains.

This is the stage of condensation (Fig. 1a).

It is replaced by what is called the stage of fragmentation, the condensed epiphysis being split up into a number of *angular or streaked but still condensed fragments* frequently separated by *considerable defects*. At the same time there will often be *flattening* of the epiphysis and *broadening of the neck*, but these phenomena depend essentially upon the treatment applied (efficacy of non weight bearing) (Fig. 1b).

This entire development—from massive condensation in an epiphysis of normal shape and size to a completely split up and deformed epiphysis may rightly be designated as constant radiological *deterioration*.

This period of "deterioration" lasts for about 18 months and not until then is a quite delicate granular new formation of bone visible in the epiphyseal defects. From this time on the healing continues, new formation of bone increases, but the bone structure in the epiphysis does not return to normal until at the end of 5–7 *years*.

The disease usually leaves a major or minor *flattening* of the femoral head and broadening of the neck—depending upon the efficacy of the treatment. These changes in shape do not immediately give rise to clinical symptoms, but may involve osteoarthritis of the hip joint at a later date (Fig. 1c).

This *typical radiological appearance and course of Legg Calvé Perthes disease* is observed mainly at an age over 6–8 years. In younger patients the appearances are not quite so typical and among the youngest group, under 4–5 years, there is *a group of patients showing an entirely different picture, radiologically as well as clinically*. In our series they make up *10 per cent* of all patients and are chiefly boy



a b c

Fig 1

Typical Legg Calvé Perthes disease

a Stage of condensation b Stage of fragmentation c Healing

just as in all other groups of the material Incidentally there are in this age group too cases of entirely typical Legg Calvé Perthes disease

When in this special group of patients we look at films of the children s hip joints *prior to* the appearance of typical radiologically changes (Fig 2 1$^{11}/_{12}$) they do not—just as in Legg Calvé Perthes disease—show a completely normal hip At this early date the hip joint (or joints) will show *a marked delay in the development of the epiphyseal nucleus* The ossification usually does not set in until about 2 years of age and when at last it starts *the small epiphyseal nucleus will be of a pathological appearance*

At the time when the patients start having constant symptoms—incidentally the same as those of typical Legg Calvé Perthes disease—the radiological appearances are as follows (Figs 2 3 4 5)

A diffuse granular structure in the small delayed epiphyseal nucleus The size of the granules ranges from millet seed to a grain of rise The epiphysis may bear a certain resemblance to a blackberry Another characteristic is that *the condensation is very inconspicuous* in these granular epiphyses It may be entirely absent but when it is present it is situated in the basal part of the epiphysis and its shape is determined by the granules which are themselves or in their periphery condensed especially down towards the epiphyseal line This gives a patchy or rather netlike basal condensation *The uniform massive diffuse condensation which is so characteristic of the typical cases of Legg Calvé Perthes disease is never seen*

The picture which has just been described is that encountered when



Fig. 9

Dysplasia epiphysealis capitis femoris dx

First picture pri r t appearance of right epiphyseal nucleus l ft Delayed epiphy eal nucleus The figures indicate the patient s ag

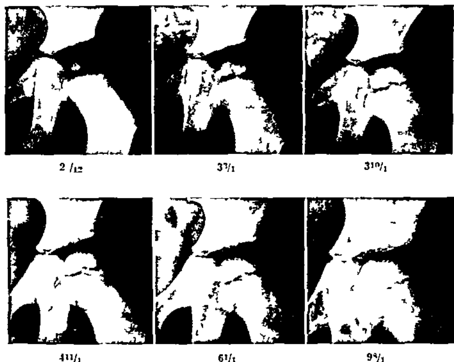


Fig 3

Dysplasia epiphysealis capitis femoris

Course until end result The figures indicate patient s age ♂

the patients are admitted for treatment *i e* it represents an early stage of the disease

A study of the *further course* (Figs 2 3 4) reveals that this too differs perceptibly from that generally seen in typical Legg Calve-Perthes disease

In the typical cases of Legg Calve Perthes disease it is characteristic that during the first 18 months or so *i e* through the fragmentation stage X rays show a striking deterioration In contrast the small group described above is characterized by *a constant improvement in the X ray appearances after the first film* There will be a steady homogenization of the epiphysis with slow disappearance of the granular structure This development until a completely normal structure is re established takes only about *3 years* while in typical Legg Calve-Perthes disease it takes 5-7 years To this is added an extremely important factor viz

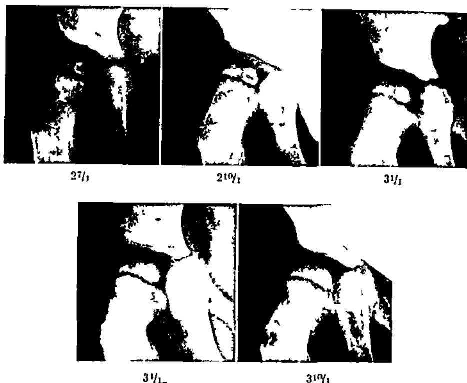


Fig 4
Dysplasia epiphysealis capitis femoris
Typical course The figures indicate the patient's age ♀

that during this course the epiphysis + neck *undergo very little deformation* There will be no essential flattening of the epiphysis or broadening of the neck In brief In about 3 years a large number of cases show the head and neck of the femur to be of *completely normal shape and structure*

Yet another two properties characterize this special type of case

It is more often bilateral than typical Legg Calvé Perthes disease (in our series in 42 per cent as compared with 7 per cent)

It is more often *familial* in the sense that there is a history in the immediate family of not only similar cases but also of other diseases of the hip (typical Legg Calvé Perthes congenital dislocation etc — *vide infra*) In our series the family history was positive for hip joint disease in 17 per cent of the special cases described above as compared with 8 per cent of the typical cases of Legg Calvé Perthes disease



Fig 5

Dysplasia epiphysealis capitis femoris

10 different examples all representing a single stage of a typical course

All ♂ Age 2 years 9 months—6 years 9 months

In order to render the following discussion of this special syndrome in young children more perspicuous it had to be given a short and convenient name For descriptive reasons we have chosen the neutral term *Dysplasia epiphysealis capitis femoris* or for short *Capital dysplasia* This was the term used in a report of these cases by *E Karup-Pedersen* in the Danish Orthopaedic Society Nov 1959

Scattered reports on similar cases have appeared in German orthopaedic literature (*Hilgenreiner*, 1936 and *Gickler*, 1937)

As is apparent from what has been stated above then our approx 300 cases of Legg Calve Perthes syndrome included at least two groups of patients having fundamentally different clinical and radiological appearances capital dysplasia and typical Legg Calve Perthes syndrome

The dysplasia occurs in children under 5 years of age in very small greatly delayed epiphyseal nuclei and manifests itself in a granular bone structure of the epiphyseal nucleus without essential condensation

By contrast Legg Calve Perthes disease was encountered in older children appearing in quite normally developed epiphysis and manifesting itself in the early stages as diffuse massive condensation of the entire capital epiphysis

This alone clearly characterizes the two syndromes but *more important still* is maybe the difference in *course* and *prognosis*

Dysplasia is headed from the very outset for *improvement* A normal bone structure is re established in about 3 years with no or *very slight change* in epiphyseal shape

In contrast the course of Legg Calve Perthes disease is characterized by *radiological deterioration* with increasing fragmentation and further flattening during the first 18 months Not until this stage does incipient scattered newformation of bone become visible leading slowly in 5-7 years to normal bone structure in a usually rather *deformed epiphysis*

The question then is Do these two characteristic syndromes represent *two entirely different diseases* or are they *merely two different manifestations of the same disease?*

There is obviously *no* question of different diseases

Despite the fact that both syndromes are extremely rare—Legg Calve Perthes disease developing in 1 out of 1000 births and dysplasia being even less common— they are relatively often *combined in the same*



Fig 6

Dysplasia epiphysealis capitis femoris with *secondary Legg Calvé Perthes disease* in the *same* hip joint

a 6 years 0 months dysplasia epiphysealis capitis femoris
b 13 years 9 months the dysplasia has disappeared capital epiphysis normal
c 14 years 1 month Legg Calvé Perthes disease stage of condensation

patient Among our 30 cases of dysplasia 6 were combined with typical Legg Calvé Perthes disease

In such *combined cases* we have the clearest and most characteristic pictures of the two types when *dysplasia occurs first and Legg Calvé Perthes disease at a later date* (incidentally we have never met with the reverse)

Two of our six combined cases were of this type (Figs 6 and 7) Considering the rare occurrence of both types it is very unlikely that we should be dealing with change coincidence in these patients

The case depicted in Fig 6 is of particular interest A 6 year-old boy was treated for typical dysplasia which healed without any sequelae After an accident at the age of 13 he developed typical Legg Calvé Perthes disease of the *same* hip Fig 7 illustrates another case A 3 year old boy was treated for typical dysplasia After it had healed the boy was allowed out of bed but supported only on the apparently normal contralateral hip which rapidly developed severe typical Legg Calvé Perthes disease

Case histories like these two must leave a definite impression that the preceding dysplacia has predisposed to the subsequent Legg Calvé Perthes disease or that there has been a common *state of preparedness* for the two conditions It must be mentioned that the two secondary cases of Legg Calvé-Perthes syndrome occurred following adequate traumas

On the other hand if two types of hip disea e *are present at the same*

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time in the same patient the radiological appearances of the dysplasia and of the Legg-Calvé-Perthes disease often turn out to be not quite so typical. Frequently both have to be characterized as *transitional cases*. One predominantly bearing the marks of dysplasia and the other of Legg-Calvé-Perthes disease.

Lastly one may not infrequently come across what might be called *pure* transitional cases, *i e* cases which cannot be classified at all as being predominantly dysplastic or predominantly Legg-Calvé-Perthes. The condensation of the capital epiphysis is considerably more marked than in dysplasia—but yet far from the massive diffuse condensation in Legg-Calvé-Perthes disease. The granular structure is *so loose* that it starts looking like fragmentation without by any means attaining the irregularly streaky and angular fragmentation of Legg-Calvé-Perthes disease. The course too occupies an intermediate position, particularly in regard to the duration.

Such "pure" transitional cases may occur in one hip only or in both hips and are *most often encountered at the age of 4–6*.

It is not, however, only in these *combined cases* and *trasitional cases* that dysplasia and Legg-Calvé-Perthes disease are associated, but they also show *familial association*. In 5 of our *30 patients with dysplasia* (17 per cent) there was a history in the *immediate* family of several cases of Legg-Calvé-Perthes disease and dysplasia. In these 5 families there was a total of not less than 11 cases of dysplasia, 9 of Legg-Calvé-Perthes disease and 2 of congenital dislocation. (The familial cases are *minimum values*, as the families were not studied systematically.)

Such an accumulation of dysplasia and Legg-Calvé-Perthes disease in a fairly small group of persons as well as the relatively common coincidence of the two conditions in the same person can certainly not be explained as a *chance coincidence* of two different diseases. Indubitably they must represent *two different manifestations of the same disease*.

But which disease? And why does it have *different radiological-clinical manifestations in the different age groups*?

← *Fig 7*

Dysplasia epiphysealis capitis femoris sin with *secondary Legg-Calvé-Perthes disease* in the *contra lateral* hip joint (which had previously been slightly dysplastic). The figures indicate the patient's age. ♂

Early X ray films and biopsy from capital epiphyses (*Jonsäter*) show without doubt that the initial stage of Legg Calve Perthes disease must represent a rather rapidly developing ischaemic *capital necrosis* i e a serious circulatory disturbance The later stages of Legg Calvé Perthes disease then merely represent the breakdown of the bone necrosis and re formation of the capital epiphysis by live bony tissue The X ray appearance of *capital dysplasia* on the other hand cannot by *any* means be interpreted as capital necrosis If anything it seems tempting to interpret it as the appearance of an *ossification diturbance* i e delayed irregular ossification Can this picture then also represent a circulatory disturbance at the site of the capital epiphysis?

By injection experiments *Truela* has demonstrated that the blood supply to the capital epiphysis is *ample in children up to the age of 4* from metaphyseal as well as from lateral and medial epiphyseal vessels *From the age of 4–8* the blood supply is far more sparse and only from one source The lateral epiphyseal vessels *From the age of 8 and until puberty* the blood supply slowly increases the vessels in the ligamentum teres starting their development However it is not until about puberty that a real improvement in vascularization takes place the epiphysis becoming again connected with the metaphyseal vessels

According to these findings it is not difficult to understand that although circulatory disturbances at an age of up to 4 years may induce disturbances of growth in the rapidly growing epiphysis it can probably not cause a complete cessation of the blood supply and subsequent capital necrosis On the other hand this must be a likely possibility in children over 4 years of age in whom the epiphysis receives its blood supply from only *one* source The lateral epiphyseal vessels In children approaching puberty the blood supply is again more ample and the growth rate slower so that the possibility of capital necrosis decreases anew

In brief According to *Truela* s findings the capital dysplasia *as well as* the Legg Calve Perthes disease may be explained as sequelae of circulatory disturbances in the capital epiphysis According to these investigations it is not surprising that circulatory disturbances at a late stage of childhood induce capital necrosis i e Legg Calve Perthes disease while at an early age they cause only ossification diturbances at the site of the capital epiphysis

However this is not saying *for certain* that the two syndromes have really been induced by circulatory disturbances at the site of the capital epiphysis but such a genesis would be *in keeping with* the view at

which we had arrived merely by clinical radiological studies That Legg Calve Perthes disease and capital dysplasia are merely two different clinical radiological manifestations due to the same cause

But if both syndromes are caused by circulatory disturbances in the capital epiphysis it is but natural that they should not be *absolutely* sharply distinguished or *completely* well defined In addition to the *typical* cases there is a certain number of *transitional* ones

Of course these transitional varieties may give rise to difficulties in diagnosis and classification

However it pays to try to group these cases between the pure dysplasias at one extreme and typical Legg Calve Perthes syndrome at the other

As a matter of fact there is a great difference between the course and prognosis of the extreme cases and by attempting to group the transitional cases in relation to the extremes we can *determine the prognosis with a far greater degree of certainty* The more pronounced the dysplastic character of a case the more it is predominated by ossification disturbances and the less by actual necrosis of bone the better is the prognosis in respect to duration as well as end result

On the other hand if necrotic changes predominate the course will be considerably longer the end result usually poorer and the treatment far more trying to the patient as well as to the doctor

As far as I can see therefore a knowledge of the two syndromes described above affords a more rational basis for *individualized treatment* of the large group of patients who have so far been referred to us as cases of Legg Calve Perthes disease

Radiological changes exactly identical with the capital dysplasia described in this paper is present in the capital epiphysis of most children with *congenital dislocation of the hip*

In children *with* as well as *without* dislocation the capital dysplasia may be followed by capital necrosis—which in children *without* dislocation is called Legg Calvé Perthes disease

Orally as well as in writing it has been maintained by several German orthopaedic surgeons but most energetically by the French author *Calot* that *Legg Calve Perthes disease* and *congenital dislocation of the hip* are merely *two different manifestations due to the same cause*—two aspects of the same disease

The *common occurrence* of the dysplasia in cases of congenital dis

location of the hip and its *close relationship* to Legg Calve Perthes di sease perhaps indicate that *maybe Calot was right!*

SUMMARY

Among the 300 cases admitted to the Coastal Hospital Refsnæs and the Finsen Institute Copenhagen as Legg Calve Perthes disease there is apart from typical cases in the younger age classes a group of cases which differ clearly from typical Legg Calve Perthes disease clinically as well as radiologically

This special syndrome is described and designated *dysplasia epi physealis capitis femoris*

The relation of capital dysplasia to typical Legg Calve Perthes di sease is described

The pathogenesis of the two syndromes is discussed on the basis of *Trueta* s studies

Attention is called to a possible pathogenetic relationship between congenital dislocation of the hip and Legg Calve Perthes disease

RESUME

Parmi 300 cas admis à l Hopital de la cote de Refsnæs et à l Institut Finsen de Copenhague souffrant de la maladie Legg Calve Perthe on a constaté en dehors des cas typiques dans les classes jeunes un groupe de cas qui different nettement de la maladie typique de Legg Calvé-Perthe aussi bien cliniquement que radiologiquement

Ce syndrome special est décrit et designe *dysplasia epiphysealis ca pitis femoris*

La relation entre la dysplasia de la tete femorale et la maladie typi que Legg Calve Perthe est decrite

Il est discute de la pathogenese de ces deux syndromes sur la base etudes de *Trueta*

L attention est attiree sur une parente pathogenétique éventuelle entre la dislocation congenitale de la hanche et la maladie de Legg Calve Perthe

ZUSAMMENFASSUNG

Unter den 300 Fallen die unter der Diagnose Legg Calve Perthes Er krankung am Kustenhospital Refsnaes und am Finsen Institut Kopen hagen aufgenommen wurden findet man abgesehen von den typischen

Fallen bei der jungeren Altersklasse eine Gruppe von Fallen die sich scharf von der typischen Legg Calve Perthes Erkrankung sowohl klinisch als auch rontgenologisch unterscheiden

Dieses besondere Syndrom wird beschrieben und als *dysplasia epiphysealis capitis femoris* bezeichnet

Die Beziehung von kopfdysplasie zur typischen Legg Calve Perthes Erkrankung wird beschrieben

Die Pathogenese beider Syndrome wird unter zugrundelegung von *Truetas* Untersuchungen besprochen

Die Aufmerksamkeit wird auf einen möglichen pathogenetischen Zusammenhang zwischen angeborener Huftverrenkung und der Legg Calve Perthes Erkrankung hingelenkt

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THE LATE PROGNOSIS AFTER FRACTURE OF THE PATELLA

By

K. HARRY SØRENSEN

Until about 15 years ago the surgical treatment of patellar fractures was usually cerclage using a steel wire or a soft suture material, or merely suture of the extensor apparatus following reduction, in some cases suture of the fragment through drill holes along the fracture. Satisfactory results from these methods are still being reported (*Bitossi* 1950, *Sabaino & Conti* 1953, *Paschold* 1958 and *Mocci & Basile* 1959), but in a number of cases the results have been unsatisfactory, especially after cerclage (*Moberg* 1944, *Marion* 1953).

Excision of one or more minor fragments combined with suture of the extensor apparatus to the largest fragment has gained some ground in suited cases (*Thomson* 1935, *McMurray* 1954, *Smillie* 1954 and *O'Donoghue* 1958), but the results have not always been good (*Duthie & Hutchinson* 1958).

After *Brooke* in 1937 introduced patellectomy and could report satisfactory results (1946), a number of authors have recommended this procedure, particularly in comminuted fractures (*Langvad Nielsen* 1954, *MacAusland* 1954, *McMurray* 1954, *Smillie* 1954, *von Rosen* 1954, *Trevor* 1957, *Fisk* 1962), or on more extended indications (*Dodd* 1939, *Fehr* 1951, *Goutz & Javelle* 1956) and even extremely wide indications (*O'Donoghue* 1958). Formerly it was believed that quadriceps strength increased during the latter part of knee extension, because the patella removed the extensor tendon from the anterior aspect of the knee and therefore gave better lever action. The adherents of patellectomy consider the role of the patella in this function to be exaggerated. Moreover deformation of the patellar joint surface following fracture is thought to increase the risk of subsequent osteoarthritis in the femoro-patellar and possibly later in the femoro-tibial articulation.

The disadvantage of patellectomy is the common occurrence of cal-cifications in the quadriceps tendon at the previous site of the patella (MacAusland 1954) The larger these calcifications the poorer the result (*Duthie & Hutchinson* 1958). Moreover the quadriceps does not regain its normal strength after patellectomy (*O'Donoghue et al* 1952).

All reported series of patellar fractures include patients on whom the follow up is far too short, viz 6 months to 5 years. In consequence the results are distorted by posttraumatic complaints and the development of osteoarthritis and its clinical significance have never been properly elucidated. Before the surgical methods and their indications are changed a series with a sufficiently long follow up period must be submitted. Cases treated without operation will serve as a good control series.

PRESENT INVESTIGATIONS

During the period Jan 1 1930 to June 5 1951 a total of 114 cases of patellar fracture were treated in the 3 surgical departments of Bispebjerg Hospital, Copenhagen. At follow up in 1961 46 of the patients *had died, 3 could not be traced (living abroad) and 1 had undergone* amputation.

TABLE 1

Age distribution and sex ratio of 64 patients with fracture of the patella

Age at accident	Male	Female
11–29 years	26	3
30–44 years	16	4
45–66 years	9	6
Total	51	13
Average age	31 yrs	42 yrs
Age at follow up	50 yrs	61 yrs
Follow up period (10–30 years)	18.5	19.3

Accordingly *64 patients were examined after a follow up period ranging from 10 to 30 years*. Their age distribution and sex ratio are *given in Table 1. The fracture* is most common in the younger age groups and four fifths of the victims were males. Six were under 14 years of age and two over 60 at the time of the accident. On an average

the males were 11 years younger than the females. At follow up the average age was 50 and 61 years respectively (30–87).

TABLE 2

Types of fracture—degree of displacement—place of accident

Type of fracture	Displacement			Total No. of pts	male
	severe	slight	none		
Transverse	9	4	15	28	
Comminuted	12	3	1	16	
Marginal	–	4	5	9	
Polar	1	1	9	11	
Total	22	12	30	64	30
Operated	19	2	1	22	
Accident: Place of work				15	
Sport				10	
At home (2), brisement (1)				3	
Traffic (females 10)				36	14
Fracture complicated (traffic 16)				21	

Table 2 gives the *type of fracture* and the *degree of displacement*. The distribution corresponds approximately to that in other series. More than half the patients sustained the accident in the *traffic*, an almost equal number being pedestrians (11), cyclists (11) and motorists (14). There was no difference in the side involved, but if excoriations are included left sided fractures were twice as often complicated as the right sided. This is due to the traffic injuries in which 12 out of 22 left sided and 4 out of 14 right sided were complicated.

Twenty two patients underwent operation: 11 by metal cerclage, 9 by suture of the extensor apparatus and 2 by excision of minor fragments. 12 of the operated and 20 of the conservatively treated patients carried a plaster cast for an average of 6½ weeks (2–11). Thirteen had evacuation of effusion by puncture. *Complications* occurred in 10 cases (including 4 operated) and consisted in pulmonary infarction in 2, patellar osteitis in 1, arthritis in 1, broken cerclage in 1 (re-operation on the 10th day) and re-fracture in 5. All the re-fractures occurred after a repeated trauma: in 2 patients having severe pareses 7 and 2 years after the first fracture, in one case by brisement 6 weeks after cerclage and in 3 non operated patients with marked displacement

(severe comminuted complicated fracture 1 severe fractures of the same leg 2 including fracture by brisement in 1)

At follow up 41 patients had been totally symptom free since the end of the primary complaints viz 65 per cent of the males and 62 per cent of the females The follow up period and the age at follow up was in both sexes the same for the symptom free and the non symptom free group Freedom from symptoms was obtained with approximately the same frequency in the various types of fracture In particular there was no significant difference between comminuted and other fractures Nor did the degree of displacement definitely influence the frequency of freedom from symptoms (Table 3) There was no significant difference between the frequency of freedom from symptoms for the operated (55 per cent) and non operated (69 per cent) patients No relation was found between the age at fracture and the frequency of freedom from symptoms The most marked difference was found between the groups under and over 30 years of age 72 per cent and 57 per cent respectively being symptom free but this difference is not significant

TABLE 3

Patients without symptoms

Type of fracture	Displacement			Total No of pts	Per cent of total series
	Severe	Slight	None		
Transverse	6	2	12	20	71
Comminuted	6	2	–	8	50
Marginal	–	1	5	6	(67)
Polar	–	1	6	7	(64)
Total symptom free	12	6	23	41	64
in per cent	55	50	73	64	
Operated and symptom free	10	1	1	12	55
Sutured 6 out of 9 Cerclage 5 out of 11 Partial excision 1 out of 2					

23 patients had suffered from *subjective complaints* from the knee invariably mild for brief periods in recent years

Stiffness in getting started	10 patients
Unrest or pain upon changes in the wheather	8 „
Pain after working or walking	10 „
Pain on walking stairs	8 „
Periodically pain at rest	2 „
Periodical swelling	2 „
Periodical limping	3 „

A total of 19 had experienced pain suggesting osteoarthritis and one had periodically suffered from symptoms caused by slight lateral instability following injury to the ligaments Nine patients had had osteoarthritic symptoms of exactly the same kind and degree from the contralateral knee

According to whether the patients work had been predominantly *sedentary standing*, or *walking* during the follow up period 9 out of 26 4 out of 8 and 10 out of 30 had experienced subjective complaints If the work is classified with a particular view to its strain on the knees 20 out of 48 with *light* and 3 out of 16 with *heavy work* had had subjective complaints In other words there is no connection between occupation and subjective complaints

Secondary incapacity due to patellar fracture after the end of the primary complaints was reported by only 3 patients of a total duration of 1 and 6 weeks and in one case for a week or two a year in association with another disease In 6 cases the sequelae of the fracture had influenced the occupation Two years after the fracture a navvy changed to other heavy work another navvy still has complaints and special work 3 independent tradesmen spare themselves from the heaviest work and one woman had lighter work for a year before returning to her former employment Furthermore 4 stated that they had been unable to work kneeling but this was of no practical importance The earning capacity had not been reduced in any case

Apart from the re fractures only 5 patients had applied for treatment owing to possible late sequelae of the fractures Three had received physical therapy and X ray therapy one only physical therapy and 1 had been treated by bed rest for a week

Physical examination revealed the following abnormalities which could not be explained on the basis of other diseases

Flexion defect in the knee	4 pts	(180/35–40–70–110)
Extension defect in the knee	1 pt	(less than 5)
Wasting of thigh	17 pts	(1–4 average 2 cm)
Wasting of calf	10 pts	(1–2½ average 1½ cm) (including 9 who also had wasting of the thigh)
Tenderness of lateral margins of patella	13 pts	(6 + tenderness on direct pressure)
Fixation of patella	9 pts	(6 treated by metal cercl[illegible])
Reduced quadriceps strength	9 pts	(7 with wasting of thigh)
Pain on strength test	*5 pts*	
Thickening of joint capsule	5 pts	(3 bilaterally)

		Contralateral knee		
		chafing	slight grating	severe grating
No chafing or grating	21 pts	0	0	0
Chafing below patella	11 pts	4	0	0
Slight grating	21 pts	3	5	0
Severe grating	11 pts	0	3	4

Thus the objective changes were moderate Chafing and grating had a tendency to be bilateral In 6 cases the objective findings were distorted by other diseases and left out of the analysis (sequelae to multiple fractures 2 severe paresis and wasting 2 sequelae to gunshot injury 1 patellar dislocation and meniscectomy 1 year previously 1)

X rays in 2 views and tangential views of the patella of both knees were obtained in all cases at follow up

TABLE 4

Osteoarthritic changes in the knees and their relation to symptoms Bilateral changes are included in the unilateral group (P patella F femur T tibia)

Change	Fractured side		Opposite side		Bilateral pts
	pts	+ symptoms	pts	+ symptoms	
Femoro patellar					
Narrowed joint space	40	18	15	6	15
Osteophytes (P)	24	9	12	3	10
Sclerosis (P)	20	11	3	2	2
F P total	45	21 = 47	*20*	6 = 30%	
Femoro tibial					
Narrowed joint space (F T usually medially only)	17	8	8	2	7
Osteophytes (F or T)	11	5	6	4	2
Sclerosis (subchond)	8	3	3	2	2
Pointed intercondyloid eminence	8	3	8	3	6
F T total	23	10 = 43%	*16*	5 = 31%	

In 8 there was *non union* of the fracture and this corresponds to the usual frequency (*Jarttinen* 1942 *Paschold* 1958) Four were symptom free and the remaining 4 did not require treatment

Table 4 gives the radiographic frequency of *osteoarthritic changes in both knees* in the total series of 64 patients and relates the individual

changes to subjective symptoms. Mild changes are also recorded. The individual changes were more common on the fractured side except for a pointed intercondyloid eminence.

A total of 45 had osteoarthritic changes in the femoro-patellar articulation on the fractured side. This is significantly more common than on the contralateral side which showed such changes in 20 cases. On the other hand only 23 had femoro-tibial changes on the fractured side as compared with 16 on the opposite side, i.e. no significant difference. Thus, at long sight, patellar fracture entails the development of femoro-patellar but not definitely of femoro-tibial osteoarthritis.

The frequency of symptoms attending the listed individual changes was approximately the same on both sides, but for the total number of femoro-patellar changes symptoms were somewhat more common on the fractured side.

In Table 5 the osteoarthritic changes are graded and related to age at follow-up. An age factor is distinctly evident, the degree of the osteoarthritis on both sides increasing significantly with advancing age. There is a significant age difference when comparing the groups with no changes with the groups having femoro-patellar osteoarthritis as well as with the groups with osteoarthritis of both the femoro-patellar and femoro-tibial articulations. The average age for the fractured side is in all groups only negligibly below the average age for the opposite side. Only a few X-ray films from the time of the fracture had been preserved, so it is impossible to ascertain how many had osteoarthritic changes then.

TABLE 5

Osteoarthritic changes in relation to patient's age at follow-up. (Bilateral changes included in unilateral groups. Age = average age in years.)

Changes	Fractured side			Opposite side			Bilateral pts
	pts	+ sympt.	age	pts	+ sympt.	age	
No changes	19	2	43	38	3	45	19
F P only	22	11	5[illegible]	10	1	56	8
F T only				6	–	63	
F P and F T	23	10	59	10	5	66	9
Total	45	21	56	26	6	6[illegible]	17

Osteoarthritic changes were least common and mildest following polar fractures not involving the joint surface (Table 6), while they

were most common and most severe after comminuted fracture. Even in the latter cases the subjective discomfort was slight. The only difference between conservatively and surgically treated cases was that 18 of the former had no osteoarthritis. The average age of these 18 patients and one operated is 43 years (Table 5).

TABLE 6

Osteoarthritic changes and their relation to type of fracture, treatment, break in contour of joint surface and to enlargement of patella

	Pts	Osteoarthritic changes		
		None	F P	F P and F F
Type of fracture				
Transverse	28	9	11	8
Comminuted	16	1	6	9
Marginal	9	3	1	5
Polar	11	6	4	1
Treatment				
Conservative	42	18	11	13
Operation	22	1	11	10
Cerclage	11	1	6	4
Suture	9	–	4	5
Part excis	2	–	1	1
Break in contour of joint surface				
1–2 mm	16	3	5	8
3–9 mm	13	–	5	8
Enlarged patella	39	4	16	19

A *radiographic break in the contour* of the joint surface on a level with the fracture was found at follow up in 29 patients. Out of these patients 16 or 55 per cent were symptom free, 9 having a 1–2 mm break in the contour while 7 had 3–9 mm. Out of 35 patients without such a break in the contour of the joint surface 25 or 71 per cent were symptom free. There is no significant difference between this frequency and the frequency of freedom from symptoms in patients with a break in the contour (55 per cent). Wasting of the thigh was found in 12 of 29 patients with a break in the contour as compared with 5 of 35 without, or 41 per cent and 14 per cent respectively, i.e. a significant difference. The break in the contour probably contributes to eliciting the symptoms but not decisively, and its significance is presumably less

than generally assumed. As may be seen from Table 6, the size of the break in the contour does not influence the severity of the osteoarthritis.

Clinically the fractured *patella was enlarged* in 31, radiologically in 39, its height, width or both being at least 5 mm. greater than on the contralateral side. In 32 cases the height was increased by 12 mm. and in 26 the width—also by an average of 12 mm. (5–27). The maximum increase was 27 × 26 mm. (Fig. 1). A radiologically enlarged patella was found in 15 out of 16 comminuted and in about half the other types of fracture. When the patella is enlarged, osteoarthritis is nearly always present (Table 6), viz. in 90 per cent, and half the patients have femoro-patellar as well as femoro-tibial osteoarthritis. 19 of the 39, or 49 per cent, had subjective complaints, as compared with 4 of 25, or 16 per cent, without enlargement of the patella.

Peripatellar calcifications, large in most cases, were found in 15, 6 of whom had subjective complaints. Ten of these patients had been treated by cerclage.

Comparison of the severity and frequency of osteoarthritis with that reported in other series is impossible, both because of the difference in the length of the follow-up period and because previous authors have given only the total frequency of osteoarthritis in per cent without specifying its nature or severity. *Madlener & Paas* (1930) reported the same frequency for conservatively and surgically treated patients, viz. 55 per cent, with bilateral changes in 22 per cent and 32 per cent respectively. *Paschold* (1958) also found no difference between conservatively and surgically treated patients, viz. 31 per cent and 27 per cent, whereas *Jarvinen* (1942) observed osteoarthritis in 28 per cent and 55 per cent respectively, i.e. the frequency was twice as high after operation. *Langvad Nielsen* (1951) reported a total frequency of 14 per cent. In other words, the frequency has been extremely varied. The methods of treatment in these series correspond approximately to those in mine.

At follow-up I advised two patients to have a minor, non-united fragment removed because of localized osteoarthritis and complaints from the knee. In one of these cases the fragment plus a small remnant of the cerclage were removed. It was only in this case plus yet another case that the cerclage was removed after the fracture had united. At follow-up the metal wire was found to have broken in 5, 2 of whom had *mild complaints*.

Even at follow-up I did not find any indication for patellectomy. The 23 patients who had complaints had only had mild, periodical and short-lasting symptoms of non-disabling nature. The function of the



Fig 1

Greatly enlarged patella in a 33 year-old man who had sustained a patellar fracture complicated by osteitis at the age of 1[illegible] The patient has had to ride a bicycle 20 km daily for many years and has been an active football player No subjective complaint except some difficulty in kneeling

knee was sufficient practically no one had needed treatment and the X ray changes alone of course did not indicate the procedure not even in the most severe cases neither on the basis of subjective complaints nor of objective and radiological findings cf Fig 2



Fig. 9.

A 64-year-old woman with severe osteoarthritis (cf. text). A 2 mm. break in the contour at the site of the fracture, a greatly narrowed femoro-patellar joint space, 2–3 mm. marginal osteophytes on the patella and femur, and sclerosis of the patella. The femoro-tibial joint space is narrowed medially, where there are osteophytes and subchondral sclerosis. Slight pointing of the eminence. Metal wire broken. The fracture is united.

This patient was a woman who was operated on for a transverse fracture with an 8 cm. wide diastasis at the age of 37, 7 months after conservative treatment elsewhere. The fragments were highly fibrous and adherent to the underlying bone; the cartilage on the femur showed severe erosions, and the knee was stiff. Following mobilization cerclage was performed. The fracture united. At follow-up 27 years later the patient had been working full time as a clerk; she rode a bicycle every day and danced a lot. She had suffered from stiffness in getting started for 2 years and pain for 3 months two years before the follow-up examination. The pain yielded to X-ray therapy. The knee moved 180–110 during marked grating, and there was a 2 cm. wasting of the thigh. X-ray films showed the most severe osteoarthritic changes in the entire series (Fig. 2). On comparison with X-ray films taken 7 years previously, there had been a marked progression of the osteoarthritic changes, which were thus partially age-conditioned. There was no indication and no desire for treatment.

CONCLUSION

There was no significant difference between the long term results following conservative and surgical treatment of the patellar fractures Thus operation according to the classical methods leaves the most severe cases just as fit as those which require no operation The frequency of osteoarthritis is approximately the same in displaced and non displaced cases and there is no difference in the severity of the changes The size of a break in contour if any does not influence the severity of osteoarthritis but is of some slight importance to the development of symptoms and signs Radiography often shows enlargement of the patella after a fracture In such cases osteoarthritis is common and frequently the patients suffer moderate complaints This group of cases always includes comminuted fractures but the changes and complaints are not severe enough to indicate patellectomy

Although metal cerclage does not yield strikingly poor results this form of treatment is considered unnecessary as the complaints involved by it may be avoided by another type of surgery

Subjective complaints are fairly seldom present 10–30 years after the fracture and like the objective changes they are of no major clinical and no occupational significance Treatment was only exceptionally needed and if so only in the form of minor procedures

Only femoro patellar osteoarthritis is significantly more common on the fractured than on the contralateral side while no such difference was found in the femoro tibial articulation The severity of the osteoarthritis increased significantly and uniformly with age on the fractured as well as on the contralateral side

In estimating the prognosis of a fracture involving a joint surface especially in compensation cases a reservation is usually made regarding the risk of developing osteoarthritis In the case of patellar fractures the practical significance of such osteoarthritis was found to be slight Generally there is a certain tendency to overestimate the clinical significance of the X ray findings but in the great majority of cases they bear no relation to the clinical condition

SUMMARY

After a follow up period of 10–30 years 64 patients with patellar fracture were seen Twenty two had been treated surgically (by cerclage or by suture of the extensor apparatus) 41 or 64 per cent had remained completely symptom free throughout the follow up period and 23 had

lately suffered from mild periodical and non-disabling osteoarthritic complaints which did not require treatment. Nine had had similar complaints from the contralateral knee. The objective changes left by the fracture were fairly slight and of no major practical significance. There was no significant difference between the results of conservative and surgical treatment. Femoro-patellar osteoarthritis was significantly more common on the fractured side (45 as compared with 20), and *femoro-tibial osteoarthritis was found in 23 on the fractured side* as compared with 16 on the opposite side, *i.e.* with no significant difference. The severity of the osteoarthritis increased significantly and uniformly with age on both sides. Breaks in the contour of the joint surface were of no importance to the development of osteoarthritis and of little clinical importance. The patella was enlarged in 61 per cent. This enlargement very often co-existed with femoro-patellar osteoarthritis and half the patients of this group had symptoms. All the comminuted fractures belonged to this group. But even in this category there was no *evident indication for primary patellectomy compared with the old* methods.

RÉSUMÉ

Après une période d'observation entre 10 et 30 ans, on a réexaminé 64 malades ayant eu des fractures de la rotule parmi lesquels *22* avaient été opérés (cerclage, suture et appareil d'extension). 41, soit 64 pour cent, n'avaient eu aucun symptôme pendant la période d'observation. 23 avaient dans les dernières années éprouvé périodiquement de légers symptômes du caractère de l'arthrose qui ne les avaient cependant pas empêchés de travailler et qui exceptionnellement avaint exigé un traitement. 9 malades avaient éprouvé des malaises similaires dans l'autre genou. Les modifications objectives consécutives à la fracture étaient assez peu importantes et sans grande importance pratique. *Il n'y avait aucune différence sensible dans les résultats entre* les cas soumis à un traitement conservateur et ceux traités chirurgicalement. Une arthrose fémoro-patellaire a été observée plus fréquemment du côté de la fracture (45 contre 20), alors qu'une arthrose fémoro-tibiale a été constatée chez 23 malades du côté de la fracture contre 16 du coté opposé, c'est-à-dire sans différence significative de fréquence. Le degré de l'arthrose s'est accru uniformément avec l'âge des deux côtés. Les saillies du contour de la surface articulaire n'ont présenté aucune importance pour l'évolution de l'arthrose et une faible importance clinique. La rotule était agrandie chez 61 pour cent. Simultanément on

constata fréquemment une arthrose fémoro-patellaire et environ la moitié des sujets présentaient des symptômes. Toutes les fractures à fragments multiples se trouvaient dans ce groupe. Mais même là l'indication d'une patellectomie primaire ne faisait pas évidence par comparaison avec les vieilles méthodes.

ZUSAMMENFASSUNG

Mit einer Beobachtungszeit von 10–30 Jahren wurden 64 Patienten mit Patellarfraktur, von denen 22 operativ behandelt worden waren (Cerclage, Sutur des Strekkapparates), nachuntersucht. 41 oder 64 Prozent waren vollständig symptomfrei unter der ganzen Beobachtungszeit und 23 hatten in den späteren Jahren leichte, nicht arbeitsbehindrende und nur ausnahmsweise behandlungserfordernde Symptome von Arthrosecharakter gehabt. 9 von diesen hatten ähnliche Beschwerden in dem anderen Knie. Die objektiven Veranderungen als Folge des Bruches waren recht gering und ohne grössere praktische Bedeutung. Kein ausschlaggebender Unterschied der Ergebnisse bei den konservativ oder operativ Behandelten war vorhanden. Femoropatellar Arthrose kam in bezeichnender Weise haufiger auf der Bruchseite vor (45 gegen 20) und femoro-tibial Arthrose kam bei 23 auf der Bruchseite gegen 16 auf der entgegengesetzten Seite vor, d.h. ohne bezeichnenden Unterschied der Haufigkeit. Der Grad der Arthrose nahm bezeichnenderweise mit dem Alter auf beiden Seiten zu. Konturunregelmässigkeiten der Gelenksflachen waren ohne Bedeutung für die Entwicklung der Arthrose und auch von geringer klinischer Bedeutung. Die Patella war in 61 Prozent vergrossert und gleichzeitig fandt man sehr oft femoro-patellar Arthrose, ebenso wie die Halfte Symptome hatte. Alle Berstungsbruche waren in dieser Gruppe. Aber selbst hier war die Anzeige einer primären Patellektomie nicht gegeben im Vergleich mit den alteren Methoden.

Statistical calculation by E. Dessau, actuary (significance level 97.5 per cent throughout).

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RÉSUMÉ

Après une période d'observation entre 10 et 30 ans on a réexaminé 64 malades ayant eu des fractures de la rotule parmi lesquels 22 avaient été opérés (cerclage, suture et appareil d'extension). 41, soit 64 pour cent, n'avaient eu aucun symptôme pendant la période d'observation. 23 avaient dans les dernières années éprouvé périodiquement de légers symptômes du caractère de l'arthrose qui ne les avaient cependant pas empêchés de travailler et qui exceptionnellement avaient exigé un traitement. 9 malades avaient éprouvé des malaises similaires dans l'autre genou. Les modifications objectives consécutives à la fracture étaient assez peu importantes et sans grande importance pratique. Il n'y avait aucune différence sensible dans les résultats entre les cas soumis à un traitement conservateur et ceux traités chirurgicalement. Une arthrose fémoro-patellaire a été observée plus fréquemment du côté de la fracture (45 contre 20), alors qu'une arthrose fémoro-tibiale a été constatée chez 23 malades du côté de la fracture contre 16 du côté opposé, c'est-à-dire sans différence significative de fréquence. Le degré de l'arthrose s'est accru uniformément avec l'âge des deux côtés. Les saillies du contour de la surface articulaire n'ont présenté aucune importance pour l'évolution de l'arthrose et une faible importance clinique. La rotule était agrandie chez 61 pour cent. Simultanément on

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COMPLETION OF GROWTH IN THE LOWER LIMBS IN RELATION TO BIOLOGICAL DEVELOPMENT MENARCHE AND INHERITED FACTORS

By

ERIK I NORDENTOFT

The literature contains numerous reports on the relation between signs of puberty inherited factors relative height during the growing period and the time of declining growth and cessation of increment in total height in children

On the other hand there seem to be sparse and divergent data on the time when longitudinal growth in the lower limbs terminates and the relation between this time puberty inherited factors and relative height during the growing period

A definite prediction of the time at which the growth of the lower limbs may be expected to cease may be of considerable clinical interest especially in the treatment of anisomelia[1] by epiphysiodesis

Wilson & Thompson (1939) found agreement between the length of the lower limbs in mothers and their daughters as well as between fathers and their sons On this basis they worked out a method for predicting the expected correction obtainable by epiphysiodesis

Gill & Abbott (1942) on the other hand found prediction of final height on the basis of parent height to be inaccurate They felt that a more accurate prediction could be obtained on the basis of relative height during the growing period Compared with children of the same age there was agreement between the relative height during the growing period and after growth had ceased

Anderson & Green (1948) were unable to confirm *Gill & Abbott*'s observations In their experience there would be a comparatively early

[1] anisomelia — unequal leg length

cessation of growth in children who had relatively long lower limbs before the age of 14, reversely growth ceased comparatively later in children whose lower limbs were relatively short during the growing period.

The relationship between the growth of the spine and of the lower limbs has been studied by *Goff* (1960). He states that as a rule growth ceases 6–12 months earlier in the lower limbs than in the spine. Investigating 200 normal children *Tupman* (1962) found that the growth of the lower limbs occurred at a steady rate, while in the spine the *growth rate varied, usually with a prepuberal spurt. Growth of the* spine continued for a considerably longer period than lower limb growth.

Gill & Abott (1942) described a method for predicting growth arrest by epiphysiodesis based on the observation that growth terminated at 18½ years of age in boys and at 16½ years in girls. Age was calculated as skeletal age on the basis of the development of the hand bones.

White & Stubbins (1944) reported that lower limb growth ceased at 16 years of age in girls and at 17 in boys.

According to *Green & Anderson* (1947) the time at which growth in the lower limbs terminated might vary by 4–5 years by chronological age but considerably less in relation to skeletal age. *In boys lower limb* growth ceased between a skeletal age of 15–17 and in girls between a skeletal age of 13–15. The increment during the last skeletal year was very slight, and for practical reasons the average time of cessation of growth was estimated as 16/3[1] in boys and 14/3 in girls. Radiological closure of the epiphysial zones occurred at the same age or at maximum intervals of a few months.

Goff (1960) found the increment in total height to cease at an average skeletal age of 17/9 (standard deviation 9.96 months) in boys and at 16.2 (standard deviation 13.6 months) in girls.

Tupman (1962) found longitudinal growth in boys to cease at an average skeletal age of 15.4 in the femur *and of 15.5 in the tibia, in* girls at an average skeletal age of 14.2 in the femur and of 13.7 in the tibia.

These previous reports on the average time at which growth in the lower limbs ceases are tabulated below (Table 1), corrected on the basis of the information given by the various authors in respect to a comparable tabulation of the results.

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1 The figure after the stroke indicates months.

TABLE 1

Age at which Growth in the Lower Limbs Terminates

Author	Skeletal age		Chronological age	
	Boys	Girls	Boys	Girls
Gill & Abott			18/6	16/3
White & Stubbins			ca. 17	ca. 16
Green & Anderson	17/3	15/3		
Goff	17/0	15/5		
Tupman	15/5	13/11		
Present study	15/0	13/6	15/8	13/11

Thus the results found in the American series of *Gill & Abott, Green & Anderson* and of *Goff* are at variance with *Tupman's* British series.

Moreover, there are divergences in the evaluation as to whether the prediction of the time at which lower limb growth ceases is more accurate on the basis of parent height or of relative height during the growing period.

Lastly, the relationship between the time of menarche and cessation of growth in the lower limbs does not appear to have been studied.

A further analysis of these factors would, therefore, seem of interest.

MATERIAL

The material—derived from the Orthopaedic Hospital, Copenhagen, Departments 1, 2 and 3—comprises 108 patients, 46 boys and 62 girls, on whom regular spot orthoradiographic measurements of the lower limbs were done at least twice before and at least once after the cessation of growth.

In all cases *the radiography* was done to measure accurately an existing anisomelia which was caused in 66 cases by the sequelae of poliomyelitis, in 8 cases by epiphysial injury, in 3 cases by fracture, in 5 cases by other factors, while in the last 26 it was congenital. Epiphysiodesis was performed before cessation of growth in 99 patients.

METHODS

The time of cessation of growth was determined on the basis of curves representing the length of the femur and tibia as a function of age (cf. Fig. 1). It was not possible in any case to demonstrate a de-

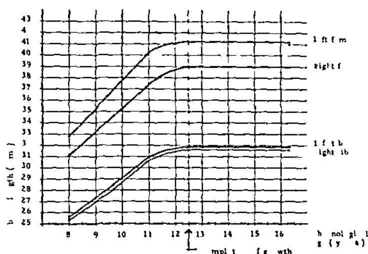


Fig 1
Example of growth curves for the femora and tibiae

finite difference between the time of cessation of growth in the femur and in the tibia

In all cases where the course of the curve after cessation of growth was based on only one measurement the epiphysial lines had closed at the time of this measurement

The material includes only cases submitted to a sufficient number of measurements at suitable intervals around the time when growth ceased so that this time could be determined with an accuracy of about 3 months

The time of cessation of growth is represented by the beginning of the horizontal part of the curve

Determination of skeletal age was done by means of the *Greulich & Pyle* (1959) method

Determination of skeletal age was performed before plotting the growth curves In cases where determination of skeletal age had not been done at the time of cessation of growth the skeletal age at this time was calculated by interpolation between the nearest determinations In a few cases in which the hand bones had completed their development when first investigated after cessation of growth the skeletal age was calculated by extrapolation from the preceding determination

Erect height without shoes was measured—in patients with anisomelia with wooden blocks under the shorter leg

In patients with a true unilateral lengthening of a lower limb the erect height was measured with weight bearing on the shorter (normal) leg

In patients who had epiphysiodesis during the growing period the erect height was corrected by adding the number of centimetres which the procedure was computed to have equalized calculated by the prediction method of *Green & Anderson* (1947)

In 2 cases the true erect height could not be measured because of structural scoliosis

In practically all cases one of the parents—in some cases both—were present at the examination In that case their erect height without shoes was measured In other cases the information regarding parent height was anamnestic In 10 instances this information was available only for one of the parents and in 4 instances for neither because of adoption or too vague data

The age at onset of the menarche could be stated with an accuracy of about 3 months—in relation to a particular event—in 40 girls

Attempts at recording the age at onset of the menarche in the mothers resulted in data which were felt to be too inaccurate to afford a definite basis for comparing the age at menarche in mothers and daughters

RESULTS

1 *Age at Cessation of Growth in Lower Limbs*

The results are given in Table 2 and Fig 2

In boys cessation of growth in the lower limbs occurred at an average chronological age of 15 8 and an average skeletal age of 15 0 years

In girls growth ceased at an average chronological age of 13 11 years and an average skeletal age of 13 6 years

The standard deviation (s_x) of the results may be seen from Table 2

It will be seen that the standard deviation (s_x) is of the same order of magnitude in both sexes but considerably greater when the time was calculated on the basis of chronological age than skeletal age

TABLE 2

Standard Deviation (s_x) for Time of Cessation of Growth in the Lower Limbs

Sex	Chronological age	Skeletal age
Boys	± 12 months 21 days	± 7 months 10 days
Girls	± 11 months 15 days	± 7 months 6 days

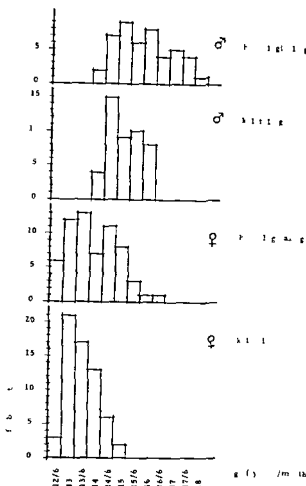


Fig 2
Age at completion of lower limb growth

Fig 2 shows that the greater standard deviation using chronological age is due to the fact that a number of the patients were late in completing their growth Thus biological development was considerably more often retarded than accelerated

2 *Final Length of Lower Limbs in Relation to Relative Length During the Growing Period*

In Tables 3 and 4 boys and girls respectively are divided into groups as far as possible equally large according to the length of the lower limbs at a skeletal age of 12 0 in the boys and 10 0 in the girls

TABLE 3

Boys

Lower limb length at skeletal age 12.0	Average skeletal age at cessation of growth	No. of observations
69.5–71.9 cm	14/11 years	10
72.3–76.4 cm	15/5 years	9
76.8–89.6 cm	14/11 years	10

TABLE 4

Girls

Lower limb length at skeletal age 10.0	Average skeletal age at cessation of growth	No. of observations
60.5–66.0 cm	13/3 years	10
66.1–68.3 cm	13/7 years	10
68.9–75.1 cm	13/8 years	10

Accordingly, the maximum variations in lower limb length at the ages concerned were 20 cm in boys and 15 cm in girls.

A total of 29 boys and 30 girls were followed from the named ages until cessation of growth. There does not seem to be any methodical difference in the length of the growing period in the different groups of patients. Thus information regarding the lower limb length about 3 years prior to the cessation of growth does not appear to afford increased security in predicting when growth will be completed.

3. *Time of Completion of Lower Limb Growth in Relation to Onset of Menarche*

Fig. 3 gives the computed results as to age at cessation of lower limb growth less age at onset of menarche. Positive statements thus signify that the cessation of growth occurred later than the menarche and *vice versa*.

It was only in 4 cases that the difference between the age at cessation of growth and the age at menarche exceeded *15 months*.

When disregarding these 4 cases, the mean value for the age at cessation of growth less the age at menarche is +4.03 months and the standard deviation (s_x) on the observations ±5.18 months.

Only in one patient did growth cease more than 4 months prior to

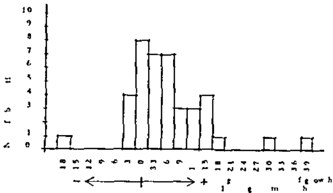


Fig 3

Difference between age at cessation of lower limb growth and age at menarche

menarche At cessation of growth this patient was 13 months biologically retarded and her erect height was identical with her mother's

In 3 patients growth ceased more than 18 months after the onset of menarche—19 31 and 40 months respectively Only one of them was biologically retarded (14 months) at completion of growth one was 5 months accelerated and in one the skeletal age was identical with the chronological age

No clinical signs of hormonal disturbances were demonstrable in these 4 patients The one in whom growth ceased 19 months after the menarche was 15 cm taller than her mother the other three 0 1 and 7 cm taller

The average age at menarche was 13 4 years (standard deviation (s_x) ±12 9 months)

The patient whose age at cessation of growth less age at menarche was calculated as −17 months did not have her menarche until 15 5 years of age and the patient in whom this value was +40 months had her menarche as early as 11/3 years of age while the patients having the values +31 and +19 had had their menarche at 13 10 and 13 5 years respectively In 2 cases the difference was thus due to a marked divergence from the average age at menarche as reported anamnestically and with the consequent inaccuracy while in the other two it was due to a marked divergence in the objectively demonstrated difference from the average age at cessation of growth

On this basis it is impossible to advance any definite explanation of the small number of individual marked divergences from the average difference between age at cessation of lower limb growth and at the onset of menarche

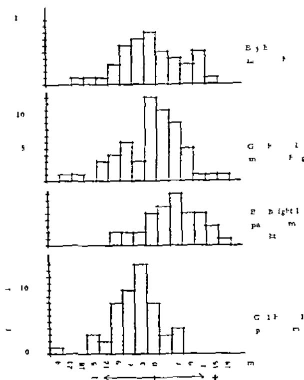


Fig 4
Difference between child height and parents height

4 *Final Erect Height in Relation to Parents Height*

Fig. 4 gives the distribution of the values representing the boys erect height less their fathers height the girls height less their mothers height and the height of girls and boys less the mean values of both parents height

The boys height was usually a little over and the girls usually a little under the mean parent height Within each sex there were marked variations (up to 25 cm) between child height and parent height Only the most marked variations can be eliminated by comparing the height with the mean value of the two parents height

DISCUSSION

The present results are based on a study of a material consisting predominantly of children suffering from more or less severe sequelae

of poliomyelitis and congenital abnormalities. However, the time of cessation of growth must be assumed to be governed by hormonal factors, and it does not appear likely that the diseases represented in the material could have influenced the hormonal factors (although it cannot be excluded). Studying 17,589 schoolgirls in Copenhagen during the period 1949–50 *Boljen, Rasch & Benzon* (1954) found the menarche to occur at the average age of 13 years 9 months, the standard deviation being ±1.0 year. The average age at menarche found in the present series, 13¾ years (standard deviation 12.9 months), is in agreement with their findings. This increases the likelihood that in the hormonal respect the series is normal.

The average age at cessation of growth found in the present series accords better with *Tupman's* British series than with the results of the American studies, which, however, show mutual divergences. This may possibly be due to a more inhomogeneous composition of the American series.

The study on the ratio of relative lower limb length during the growing period to the final lower limb length was based only on a small series of inhomogeneous composition, so that the results can be merely of orientating significance. Since growth in the lower limbs and in the spine does not cease at the same time, these two phenomena may be governed by different hormonal factors. Consequently, it is not possible to draw direct conclusions analogous to the ratio total height during the growing period to that after cessation of growth. Further elucidation requires a larger and more homogeneous material.

Long-lasting disease and surgical procedures may have retarded longitudinal growth in a number of the present patients. Therefore, the results of the study on the ratio child height to parent height are not comparable with corresponding studies of normal series. On the other hand, it is usually in this very type of case that epiphysiodesis is indicated. On the basis of the marked variations between child height and parent height it may therefore be concluded that considerable errors may be involved by a calculation of the expected correction (cf. *Wilson & Thompson*) by epiphysiodesis—on the assumption that children will attain the same height as their parent of the same sex.

SUMMARY

Based on repeated orthoradiographic measurements in 46 boys and 62 girls lower limb growth was found to cease at an average chrono-

logical age of 15 8 years and an average skeletal age of 15 0 years in boys and at an average chronological age of 13 11 years and an average skeletal age of 13 6 years in girls The standard deviation was in both sexes about 12 months according to chronological age and about 7 months according to skeletal age

Information on the height in relation to children of the same age during the growing period does not appear to increase the accuracy in predicting the time of completion of lower limb growth

In 36 girls lower limb growth ceased an average of 4 months after the menarche Only in 4 did the difference exceed 15 months

Analysis of the relation between total height in 104 full grown children and their parents indicated that prediction of the correction obtainable by epiphysiodesis will be inaccurate if it is based on the ratio patient height to parent height

RESUME

En se basant sur des mensurations orthoradiographiques repetees de la croissance des membres inferieurs chez 46 garçons et 62 filles on a constate que la croissance cesse a une moyenne d age chronologique de 15 8 et une moyenne d age squelettique de 15 0 ans chez les garçons et a une moyenne d age chronologique de 13 11 et une moyenne d age squelettique de 13 6 ans chez les filles L ecart standard pour les deux sexes etait d environ 12 mois par rapport a l age chronologique et d environ 7 mois pour l age squelettique

Des renseignements sur la grandeur par rapport aux enfants du meme age pendant la periode de croissance ne semblent pas accroitre la precision avec laquelle on peut predire l achevement de la croissance des membres inferieurs

Chez 36 filles la croissance des membres inferieurs avait cesse en moyenne 4 mois apres la menstruation Chez 4 seulement la difference a excede 15 mois

Une analyse entre la grandeur totale de 104 enfants ayant acheve leur croissance et celle de leurs parents indique que la prediction de la correction qui peut etre obtenue par epiphysiodese ne sera pas exacte si elle est basee uniquement sur le rapport direct entre la grandeur du sujet et celle de ses parents

ZUSAMMENFASSUNG

Auf Grund von wiederholten orthoradiographischen Messungen in der unteren Extremitet von 46 Knaben und 62 Mädchen wurde gefunden dass das Wachstum in einem durchschnittlichen chronologischen Alter von 15/8 Jahren und einem durchschnittlichen Skeletalter von 15/0 Jahren bei Knaben und in einem durchschnittlichen chronologischen Alter von 13/11 Jahren und einem durchschnittlichen Skeletalter von 13/6 Jahren bei Mädchen aufhort Die Durchschnittsabweichung war bei beiden Geschlechtern ungefähr 12 Monate hinsichtlich des chronologischen Alters und ungefähr 7 Monate hinsichtlich des Skeletalters

Aufschluss uber den Hohenwuchs während der Wachstumperiode in bezug zu Kindern des gleichen Alters scheint die Genauigkeit der Vorhersage uber den Wachstumsabschluss der unteren Gliedmasse nicht zu vermehren

Bei 36 Mädchen horte das Wachstum der unteren Gliedmasse durchschnittlich 4 Monate nach der Menarche auf

Die Analyse der Beziehung zwischen Gesamthohe bei 104 voll erwachsenen Kindern und deren Eltern zeigte dass die Vorausbestimmung der durch Epiphyseodesis erhaltbaren Korrektur ungenau sein wird wenn ihr das Verhältnis der Patienten Hohe zur Eltern Hohe zu grunde gelegt wird

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STATOMETRIC STUDIES ON PATIENTS OPERATED UPON FOR SLIPPED DISC IN THE LUMBAR REGION

By

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INTRODUCTION

Measurement of "posture", i.e. the measurement of the spatial orientation of the body in the erect position, has been attempted by many authors who have used different methods. However, the principles are approximately the same: Trying to gain an objective impression of the body orientation in the erect position by photography, X-rays, or measurement direct on the body surface using the plumb line as a line of reference.

By means of a cheap apparatus and a simple method *Mølhave* (1958) has worked out a method for measuring the spatial orientation of the body in the erect position.

Without discussing the concept good and poor posture, I should like to point out that in 1867 *Duchenne* noted the marked individual variations. He writes (*Kaplan*'s translation 1949): "Thus, for instance, the Spanish women and especially the Andalusians are known to possess beautiful spinal curves." And later: "Women who have a very straight vertebral column or otherwise slightly flexed, have generally speaking a straight body with angular contours; the lines of their neck and shoulders are not graceful . . . the origin could well be Anglo-Saxon."

The object of the present study was to ascertain changes in the spatial orientation of the lumbar column and pelvis during the first 2 or 3 months after operation for slipped lumbar disc.

STATOMETRIC STUDY

It is a common finding that patients with slipped lumbar disc have preoperatively as well as postoperatively a diminished or obliterated lumbar lordosis, at times even a slight lumbar kyphosis.

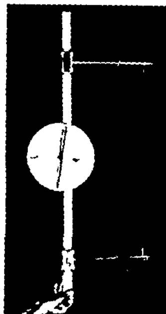


Fig 1



Fig 3

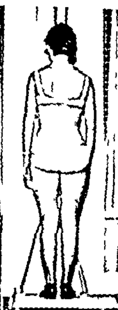


Fig 2

Fig 1 Statometer

Fig 2 Dorsal Landmark

Fig 3 Landmarks on the lower limbs. The inclination between the vertebral prominens and interspination is demonstrated

In an attempt at confirming objectively the above mentioned clinical findings, patients who had undergone operation for slipped lumbar disc were subjected to measurement of the spatial orientation of the spine, pelvis and lower limbs in relation to the plumb line, the so-called statometry of *Molhave*. Three measurements were performed in each case: the first 3–4 weeks after the operation, the second after the completion of the postoperative rehabilitation period and the third at follow up about two years after the operation.

Statometry by the method of *Molhave* is carried out as follows.

The examination is performed by specially trained physiotherapists using an apparatus called a statometer.

Fig. 1 illustrates a statometer, the recording disc and its pointer suspended in a ball bearing.

In order to be able to reproduce the same standing position accurately during the entire measuring procedure the position has to be recorded. This is done by a direction finder, the two vertical direction rods being

placed in the same frontal plane as the tragus and the position is read on the horizontal scale (= indicator point) (cf Fig 3 top)

The subject is wearing his usual shoes with flat heels

The following landmarks are recorded

(1) Tip of the lateral malleolus (2) lateral femoral epicondyle (3) middle of upper edge of greater trochanter (4) posterior superior iliac spines and a point midway between these two called interspinalion (5) deepest point of lumbar lordosis (6) summit of thoracic kyphosis (7) the vertebra prominens (8) anterior edge of mastoid process

Fig 2 sets out the marking of the dorsal landmarks Fig 3 that of the landmarks on the lower limbs

While the patient is in the intention position *i e* the standing position assumed before he starts walking (*Mollhave*) the physiotherapist measures by means of the statometer the inclination in relation to the plumb line of

(1) The lower limb (a) from the tip of the lateral malleolus to the greater trochanter (b) from the tip of the lateral malleolus to the lateral femoral epicondyle (c) from the lateral femoral epicondyle to the greater trochanter

(2) The pelvic inclination From the pubic tubercle to the posterior

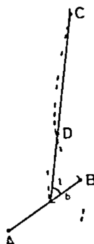


Fig 4
A tuberculum pubicum B spina iliaca post sup
CD lumbo-dorsal line

iliac spine. However, this is measured in relation to the horizontal plane.

(3) Trunk. From the greater trochanter to the mastoid process.

(4) Spine. From the interspinalion to the vertebra prominens (cf. Fig. 3).

(5) Thoracic kyphosis. (a) From the indicator point to the summit of the thoracic kyphosis = the dorso-cervical line. (b) From the latter point to the deepest point of the lumbar lordosis = the lumbo-dorsal line.

(6) Lumbar lordosis. (a) Lumbo-dorsal line. (b) from the deepest point of the lumbar lordosis to the cornu of the sacral bone = sacro-lumbar line.

However, it often proved very difficult to determine with certainty the situation of the cornu of the sacral bone, so the sacro-lumbar line was not recorded. Instead we determined the angle between the lumbo-dorsal line and a plane through the pubic tubercle and posterior superior iliac spine (= pelvic inclination) as an indicator of the lumbar lordosis. Fig. 4 shows that the angle l between the plane of pelvic inclination and the lumbo-dorsal line may be expressed by the following equation:

$$\angle l = 90 - (b + c)$$

On the figure points A and B represent the pubic tubercle and the posterior superior iliac spine respectively. Line CD represents the lumbo-dorsal line. ∠ b = pelvic inclination, and ∠ c = the inclination of the lumbo-dorsal line.

The distal part of the lumbar column follows the movements of the pelvis. A reduction in the pelvic inclination increases the angle between this plane and the lumbo-dorsal line, i.e. the lumbar lordosis becomes less concave. If the pelvic inclination increases, the concavity of the lumbar lordosis will increase, provided that the inclination of the lumbo-dorsal line is not reduced.

NORMAL VALUES

Molhave's normal values, based on the statometric study of 106 men and 104 women, are as follows:

8 lower leg 5 ± 2, thigh [illegible] ± 2
Lower limb 5 ± 1, Pelvis 37 ± 4
Inclination of trunk 0 ± 2, Inclination of spine 2 ± 2, Dorso-

cervical line 16 ± 2 Lumbo-dorsal line —10 ± 3 Lumbo sacral line 8 ± 4

♀ Lower leg 5 ± 2 thigh 6 ± 2

Lower limb 6 ± 1 Pelvis (pelvic inclination) 35 ± 4 Inclination of trunk —2 ± 2 inclination of spine 2 ± 2 Dorso-cervical line 15 ± 2 Lumbo-dorsal line —10 ± 3 Sacro-lumbar line 8 ± 4

The angle between the lumbo dorsal line and the pelvic inclination averages 44 ± 5 in both sexes

All the above mentioned measurements were performed but in the present paper we shall be concerned merely with the results representing the pelvic inclination and the lumbar lordosis as well as the inclination of the lower limbs (i e lateral malleolus to greater trochanter) and of the spine as a whole (interspinalion to the vertebra prominens)

FIRST STATOMETRIC STUDY 3–4 WEEKS AFTER THE OPERATION

As already mentioned the present study was designed to ascertain whether patients who have undergone operation for slipped lumbar disc exhibit deviations from normal in respect to the spatial orientation of the lumbar column and pelvis and whether these factors alter in the course of the postoperative period of rehabilitation

The following requirements had to be fulfilled in order to perform statometry

(1) The patient had to be able to support equally on both legs i e not have pain in the lower limbs which prevented a normal standing position

(2) There must not be major degrees of scoliosis of the thoraco lumbar spine

(3) There must not be low back pain causing fixation of the lumbar column

Originally the series comprised 125 patients who had undergone operation for slipped lumbar disc but only 85 were estimated to fulfill the above mentioned criteria

The patients did not differ in age distribution or operative findings from other large operated series (*Busch et al* 1949 *Shinners & Hamby* 1949 *Gottschalck & Hojgård* 1961)

Table 1 presents the results of the investigation 3–4 weeks after the operation

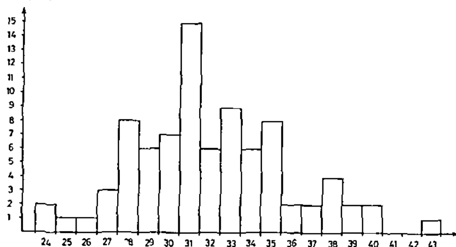

1 st examination 3–4 weeks after the operation
Pelvic inclination
No of patients
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
Pelvic inclination in

Fig 5

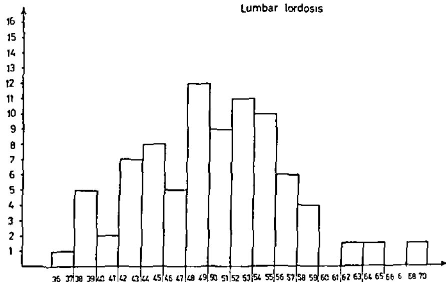

No of patients
1 st examination 3–4 weeks after the operation
Lumbar lordosis
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Lumbar lordosis in

Fig 6

TABLE 1

Statometric Examination 3–4 Weeks after the Operation 85 Patients

		Normal value	Significance
Lumbar lordosis	50 6 ± 6 3	44 ± 5	0 001 >
Pelvic inclination	3[illegible]1 ± 3 7	36 ± 4	0 001 >

The pelvic inclination as well as the degree of lumbar lordosis differed significantly from normal values

Fig 5 gives the distribution of the pelvic inclinations It shows that only a few patients had a pelvic inclination between 35 and 37 the majority being in the range 28 –33

Fig 6 presents the distribution of the lumbar lordoses Clearly about half the patients had a lumbar lordosis of between 48 and 56 while the normal value is 44

Therefore it must be concluded that many patients who have undergone operation for slipped lumbar disc have a low pelvic inclination and a flattened lumbar lordosis As a whole the group differs significantly from a normal group both in respect to pelvic inclination and degree of lumbar lordosis

The inclination of the lower limbs for the group as a whole was 4 1 ± 2 (normal value 5 ± 1) and that of the spine as a whole 3 0 ± 2 6 (normal value 2 ± 2) These values differ significantly from the normal values (0 01 < p < 0 001) Thus there is a tendency to carry the trunk forward and the lower limbs backward

SECOND STATOMETRIC STUDY AT COMPLETION OF REHABILITATION PERIOD

During the first 8–10 weeks after the operation the patients were treated by (1) resistance exercises for spinal muscles gluteal muscles and the muscles of the lower limbs (2) limbering up exercises for the lumbar column (3) massage and heat treatment

After this treatment was completed another statometric study was performed

The results of this study were then to be compared with those of the statometry done 3 4 weeks after the operation

Which criteria have to be fulfilled in order to compare two statometric studies?

The primary requirement must be that on repeated investigations of the same patient there are not major variations in the results owing to inaccuracy of measurement.

Volhave demonstrated that on repeating the measurement the difference is usually *not greater than = 1°, in rare cases 2°.*

In the second place it must be demanded that for assessing alterations in the pelvic inclination or of the lumbar lordosis, the standing position should not as a whole differ essentially from one measurement to the other. In other words, the inclination of the lower limbs (measured from the tip of the lateral malleolus to the middle of the upper edge of the greater trochanter) and the inclination of the spine as a whole (measured from the interspination to the vertebra prominens) must not differ essentially from one measurement to the other.

Therefore, the following criteria for the comparability of two statometric studies were set up:

The inclination of the lower limbs must not vary by more than ± 2° from one measurement to the other.

The inclination of the spine as a whole must not vary by more than ± 2° from one measurement to another.

When these criteria are observed, an increase in pelvic inclination, for instance, cannot be due to forward bending of the entire spine and pelvis, but it must be an isolated alteration in the orientation of the pelvis. Similarly, an increase in lumbar lordosis cannot be explained by backward extension of the trunk.

Moreover, it has been demonstrated by *Floyd & Silver* (1955) that the minor oscillations which constantly occur in the standing position take place almost exclusively in the ankle joints. This means that the curvatures of the spine are practically *independent of the slight alterations* in the inclination of the lower limbs.

Provided that the above mentioned criteria are observed, the statometry of 67 patients performed 3–4 weeks after the operation is comparable with that *performed at the end of the rehabilitation period.*

From Table 2 it may be seen that there had been a significant increase in the pelvic inclination and a significant accentuation of the lumbar lordosis. The accentuation of the lumbar lordosis (i.e. the diminution of the angle between the lumbo-dorsal line and the pelvic inclination) is twice as marked as the alteration of the pelvic inclination. This shows that the alteration is not localized merely to the distal part of the lumbar column and pelvis, but also to the proximal part. These values differ significantly from the normal values ($p < 0.001$).

TABLE 2

Alterations in Pelvic Inclination and Lumbar Lordosis during the Rehabilitation Period 67 Patients

	First statometry 3-4 weeks after the operation	Statometry at the end of the rehabilitation period	Significance
Pelvic inclination	32.28 ± 3.8	34.73 ± 2.9	< 0.001
Lumbar lordosis	50.23 ± 5.6	40.55 ± 4.5	< 0.001

TABLE 3

	Pelvic inclination at 1st measurement 3-4 weeks after the operation	Lumbar lordosis at 1st measurement 3-4 weeks after the operation
Patients showing changes in pelvic inclination of 2° or over during the postoperative period 38 patients	30.4 ± 2.52	53.45 ± 4.2
Patients showing no changes in pelvic inclination ±1° during the postoperative period 29 patients	34.76 ± 3.83	46.96 ± 5.4
Significance	P < 0.001	P < 0.001

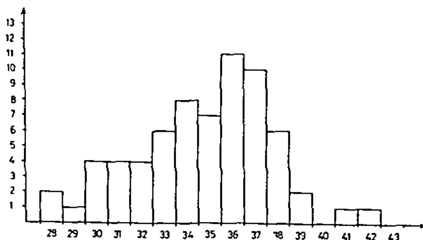


Fig 7

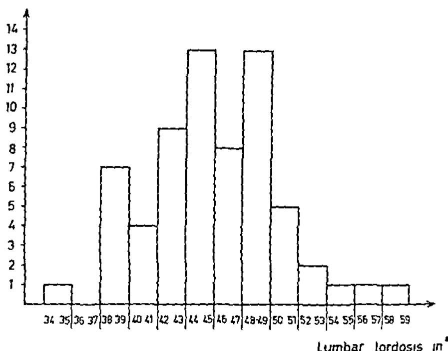


Fig 8

Table 3 demonstrates that alterations in pelvic inclination of 2° or over occur particularly in patients who showed at the first investigation a slight pelvic inclination and a flattened lumbar lordosis In patients who did *not* exhibit an alteration of the pelvic inclination of more than 1 the values had been close to normal on occasion of the first statometry

Fig 7 shows the distribution of the values found for pelvic inclination A comparison with Fig 5 reveals that a shift has taken place towards higher values the greater part of the values being about 35 –37 *i e* close to the normal values found by *Molhave*

Fig 8 gives the distribution of the angles found between the lumbo dorsal line and the pelvic inclination *i e* the lumbar lordosis Comparison with Fig 6 shows in this respect *too* a clear shift towards lower values

Summing up it may be concluded that many patients who have

undergone operation for slipped lumbar disc show a dysstatic condition of the lumbar column and the pelvis manifesting itself in a reduced pelvic inclination and a flattened lumbar lordosis

After the operated patients have been through a period of rehabilitation the pelvic inclination and the degree of the lumbar lordosis often approach normal However the group as a whole differs significantly from *Mølhave*s normal values ($p < 0.001$)

The present study however does not permit the final conclusion that the alterations represent a direct consequence of the exercise therapy as we have no control group But it seems reasonable when other factors indicate exercise therapy to give the patients a treatment which supports a possible spontaneous tendency to normalizing the static conditions in the lumbar spine and pelvis

THIRD STATOMETRIC STUDY ABOUT 2 YEARS AFTER THE OPERATION

A repeated statometric study was carried out at follow up an average of 25 5 months after the operation

A source of error in the statometric study performed at the completion of the rehabilitation period might be that in the course of the daily exercise therapy the patients had got a feeling that they were expected to be able to produce a lumbar lordosis Consciously or unconsciously they might therefore have assumed an artificially increased pelvic inclination and an increased lumbar lordosis at the time of the measurement

Such a motive would probably not play any role at follow up so many months after the operation The patients have then presumably forgotten both which exercises they did and the motivation for performing them

An unchanged statometric result at follow up would mean that the alterations occurring in the first 2 or 3 months after the operation were permanent and not a result of a temporarily acquired posture

A comparison of the values found at follow up with those observed at the completion of the rehabilitation period could be made in only 56 of the 67 patients partly because some of them failed to attend follow up and partly because of the above mentioned criteria

Table 4 shows no significant difference between the two studies neither in respect to the degree of pelvic inclination nor of lumbar lordosis

TABLE 4

Statometric Examination at Follow Up about 25 Months after the Operation

	Statometry at the termination of the rehabilitation period	Statometry at follow up	Significance
Pelvic inclination	34.73 ± 2.9	34.27 ± 3.2	> 0.1
Lumbar lordosis	46.55 ± 4.5	47.47 ± 4.9	> 0.1

Then it must be concluded that the increase in pelvic inclination and the diminution of the angle between the lumbo dorsal line and the plane of inclination observed in the *postoperative rehabilitation period* are not temporarily acquired but permanent alterations

SUMMARY

The method of *Molhave* for measuring the spatial orientation of the body is described This method is called statometry Only the results in respect to pelvic inclination lumbar lordosis inclination of the lower limbs and of the spine as a whole were used in the present study

Out of a series of 125 patients who had undergone operation for slipped lumbar disc 85 were subjected to statometry 3–4 weeks after the operation At the completion of the postoperative rehabilitation period the patients were re examined but the results were comparable in only 67 About 2 years after the operation a follow up statometry was *performed*

At the time of the first statometry the group as a whole showed significant differences from *Molhave's* normal values in respect to the degree of pelvic inclination and of lumbar lordosis the pelvic inclination being diminished and the lumbar lordosis flattened

After the rehabilitation period these factors had altered The pelvic inclination had increased and the lumbar lordosis had been re established but without returning quite down to *Molhave's* normal values

At follow up about 2 years after the operation the group as a whole showed an unchanged pelvic inclination and lumbar lordosis as compared with the results at the end of the rehabilitation period

Therefore it seems rational to subject patients of this category to postoperative exercise therapy aiming at increasing the pelvic inclination and re establishing the lumbar lordosis

RESUME

La méthode de *Volhave* pour mesurer l orientation spatiale du corps est decrite Cette methode est appelee statometrie Seuls les resultats concernant l inclinaison pelvienne la lordose lombaire l inclinaison des membres inferieurs et de l ensemble de la colonne vertebrale ont ete *utilises dans la presente etude*

Sur une serie de 125 malades avant ete operes pour hernie discale lombaire 85 ont subi un examen de statometrie 3–4 semaines après l opération A la fin de la periode de readaptation post-operatoire les malades ont ete réexamines mais les resultats n ont ete comparables que dans 67 cas seulement Environ 2 ans apres l operation une statometrie de contrôle a ete pratiquee

A l epoque de la premiere statometrie on a constate dans l ensemble du groupe une difference marquee par rapport aux donnees normales de *Volhave* concernant le degre d inclinaison pelvienne et de lordose lombaire l inclinaison pelvienne etant diminuee et la lordose lombaire aplatie

Après la periode de readaptation ces facteurs s etaient alteres L inclinaison pelvienne avait augmente et la lordose lombaire avait ete retablie mais sans revenir entierement aux donnees normales de *Volhave*

Au reexamen environ 2 ans apres l operation le groupe avait dans *l ensemble une inclinaison pelvienne et une lordose lombaire in*changees par comparaison avec les resultats releves a la fin de la periode de readaptation

Il parait rationnel dans ces conditions de soumettre les malades de cette categorie a une therapie d exercices post operatoires susceptibles d accroitre l inclinaison pelvienne et le retablissement de la lordose lombaire

ZUSAMMENFASSUNG

Die Methode von *Volhave* zur Messung der räumlichen Orientierung des Korpers wird beschrieben Diese Methode wird Statometrie genannt Die Ergebnisse hinsichtlich Beckenneigung Lendenlordose Neigung der unteren Gliedmassen und der Wirbelsäule als Ganzes wurden allein in dieser Untersuchung verwendet

Von einer Reihe von 125 Patienten die einer Operation wegen vorgefallener Lendenzwischenwirbelscheibe unterworfen worden waren wurden 85 drei bis vier Wochen nach der Operation mittels Stato

metrie untersucht. Nach Vollendung der postoperativen Wiederherstellungsperiode wurden die Patienten wiederuntersucht. Das Ergebnis war jedoch nur bei 67 Patienten vergleichbar. Ungefähr zwei Jahre nach der Operation wurde eine Nachuntersuchung mittels Statometrie ausgeführt.

Bei der ersten Statometrie zeigte die Gruppe insgesamt bezeichnende Abweichungen von *Völhaves* normalen Werten hinsichtlich des Grades der Beckenneigung und der Lendenlordose, indem die Beckenneigung verringert und die Lendenlordose abgeflacht war.

Nach der Wiederherstellungsperiode hatten sich diese Faktoren verändert. Die Beckenneigung hatte zugenommen und die Lendenlordose war wiederhergestellt, jedoch ohne die normalen Werte von *Volhave* ganz zu erreichen.

Bei der Nachuntersuchung ungefähr 2 Jahre nach der Operation zeigte die Gruppe im Ganzen eine unveränderte Beckenneigung und Lendenlordose im Vergleich mit dem Ergebnis am Ende der Wiederherstellungsperiode.

Es erscheint daher logisch, derartige Patienten einer postoperativen Übungsbehandlung, die auf die Zunahme der Beckenneigung und Wiederherstellung der Lendenlordose abzielt, zu unterwerfen.

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TRAUMATIC SEPARATION OF THE UPPER FEMORAL EPIPHYSIS AS AN OBSTETRICAL LESION

By

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Two case histories of traumatic separation of the upper femoral epiphysis during delivery will primarily be presented including radiograms up to four years after birth. Problems of diagnosis and treatment and the incidence of this lesion, infrequently mentioned in the literature, will secondarily be discussed.

CASE HISTORY

I. 12.6.1958 a full term baby boy was delivered at a clinic during rather dramatic circumstances. Twice the mother had had a still born child. The umbilical chord was incarcerated between the head and the pelvis and the obstetrician had to perform inled podalic version and forceful extraction on the left leg. Three days later the boy was sent to department III of the orthopaedic hospital on the diagnosis of fracture of the left femur.

On admission the entire left femur was swollen with firmness at the upper end, bruises around the left ankle and foot. No active movements of the left hip joint, but on passive movements strepitus or crepitus in a haematoma could be felt. The X-rays—Fig. 1—showed a displacement of the shaft of the femur laterally and upwards, most marked in the Lauenstein projection, and swelling of the soft tissue around the upper end of the femur. The picture could be mistaken for a congenital dislocation of the hip. But considering the signs of a traumatic lesion we felt it was a case either of a separation of the upper femoral epiphysis or a traumatic hip dislocation. The boy was for 6 weeks put on a Jones splint with longitudinal traction in abduction, slight inward rotation and with cross traction medially. It was felt that in case a separation of the upper epiphysis had taken place callus or calcification in the haematoma early would be demonstrable. The X-ray 7 days later—Fig. 2—showed however only some improvement in the position of the shaft of the femur. No callus or periostal separation along the shaft can yet be seen.—The cross traction medially was increased.—Calcification in the haematoma or callus and periostal separation along the femoral shaft can be seen on the next X-ray—Fig. 3—taken 20 days after birth.

At the time the boy was taken out of the frame and traction discontinued the



Fig 1

3 days after birth

Case I X rays show a displacement of the shaft of the femur laterally *and upwards*, a picture similar to a dislocated hip



Fig 2

10 days after birth

Case I X ray shows only some improvement in the position of the shaft of the femur No callus or periostal separation along the shaft can yet be seen



Fig 3

20 days after birth

Case I X ray shows callus and periosteal separation along the femoral shaft

X rays—Fig 4 -show that remodelling processes have started The position of the femur in relation to the acetabulum seems not to be very satisfactory but on clinical examination there was no deformity and full active movements were all ready restored

Although we felt a traumatic dislocation of the hip joint had not taken place and the separation of the epiphysis had healed up with some angulation we felt



Fig 4
C ueeks after birth
Case I X rays taken after traction vas disc ntinued full active movements restored and no clinical def rmity was evident Remo lelling processes have started



Fig 5
4 months after birth
Case I X ras sh w a lvanced remo lelling of the ; eric stal new l ne and disapj earance of the callus



Fig 6
7 months after birth
Ca e I X rays show a varus def rmity and a l ackwards-open angulation of the gr wn neck of the femur The c sification centres of the heads are now also visible

to l an arthrc gram but fail d An arthrographia wa later not attempted due to a throat infection

Tw m nths after birth the l wa ent h me with ut any kind of bandaging Two months later X rays—Fig 5— h w a lvanced remodelling of the periostal new l one an l di appearance f the call : The neck ha grown in length with some varus



Fig 7
4 years after birth
Case I X rays show some hypertrophy of the head neck and shaft of the femur The varus deformity of the neck has disappeared only a somewhat reduced anteversion is present

deformity and a backwards open angulation as seen in the Lauenstein projection This deformity is even better shown on the next X rays—Fig 6—taken 7 months after birth The ossification centres of the heads are now also visible

The boy was last seen four years old There is no limitation of hip movements no limp Leg lengths are equal—also on X ray measurements The last X rays are shown on Fig 7 A moderate broadening of the neck and a reduced anteversion are the only sequels after the primary angulation due to the epiphyseal separation

At Allmanna Sjukhuset Malmo a very similar case has been seen[1]

II 1 12 1958 a full term baby girl was delivered at the obstetrical department by forceful extraction on the foot which together with the umbilical cord was present in the vulva There was very feeble pulsation to be felt in the cord and quick delivery



Fig 8
4 days after birth
Case II Similar displacement as in Case I Fig 1

1 I am grateful to Dr Sophus von Rosen for the opportunity given me to report this case



Fig 9

5 and a half weeks after birth

Case II Callus and periostal separation indicating repair of a separation of the epiphysis Similar alterations as in Case I Figs 3 and 4 twenty days and seven weeks after birth

was necessary — Four days later a swelling of the left femur was observed X ray—Fig 8—indicated "no sign of fracture" No treatment was given

The baby was sent to the orthopaedic department 9 1 1959 as the swelling had not subsided Slight outwards rotation in left hip and a firm swelling around the trochanter were observed It was felt that the hip was not dislocated and leg lengths were equal X ray—Fig 9—five and a half weeks after birth indicated that a separation of the upper femoral epiphysis had taken place due to callus formation around the upper end of the femur

The girl was seen at the out patient clinic with regular intervals To begin with some reduction in inward rotation of the left hip was noticed The girl did not walk before one and a half year of age At the last examination when she was 4 years of age no limitation of hip movement was demonstrable and leg lengths were equal X rays were taken 3 and a half months after birth—Fig 10—8 and a half months Fig 11—one and a half year—Fig 12—and 4 years and two months after birth—Fig 13 The radiographic series shows a remodelling process with broadening of the neck and metaphysis and a varus deformity with backwards-open angulation of the femoral neck similar to the development as in Case I

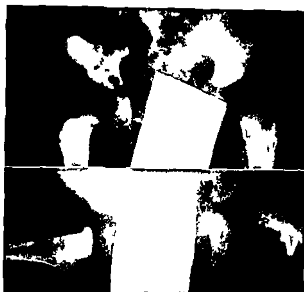


Fig 10
3 and a half months after birth
Case II Some deformity in varus and a backwards open angulation as in Case I Fig 5 four month after birth

The end result after four years however is only a minor deformity in varus Lauenstein s projection has not been employed so it is not known whether the back wards angulation during growth has been reduced to a similar degree as in Case I

DIAGNOSIS

We have been unable in the literature to find any report of a traumatic hip dislocation proved to be an obstetrical lesion *Nathan* (1928) and *Puppel* (1930) have reported on a single case each and believe they have proved that such a condition exsists However their case histories and radiograms are similar to the above reported cases and with no doubts their cases have been instances of traumatic separation of the upper femoral epiphysis *Elizalde* (1946) has reported on two cases he believes are fracture dislocations due to obstetrical trauma He realises that in his two cases there was a fracture or a separation of the epiphysis in the upper end of femur but he is of the opinion that additional a dislocation of the hip had taken place His illustrations and the course of the disease however does not prove that such was the case Both children were treated by closed reduction of the hip and put in plaster in the so called Lorenz II position for 45 days

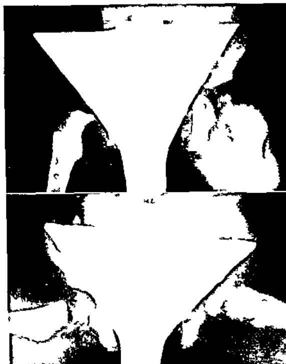


Fig 11
8 and a half months after birth
Case II Same deformity similar to Case I Fig 6 seven months after birth

Lorenz in his monograph on congenital dislocation of the hip (1920) is of the opinion that a traumatic obstetrical hip dislocation does not exist as he had not seen a single one among his around 1 000 cases of congenital hip dislocations

Harrenstein (1929) and *Michail Theodorou Houliaras & Statis* (1958) believe as we do that the above reported cases and a further series from the literature are not obstetrical traumatic hip dislocations *Harrenstein* performed on two still born children experiments in order to produce a hip dislocation In both instances a separation of the upper epiphysis was produced but no dislocation in the hip joints occurred

It can be concluded that a traumatic hip dislocation during delivery has never been reported —The diagnosis of a traumatic separation of the upper femoral epiphysis is based upon the history of delivery functio laesa clinical fracture signs related to the upper end of femur



Fig. 12

1 and a half year after birth

Case II. Broadening of the neck and metaphysis with some varus retroversion deformity.

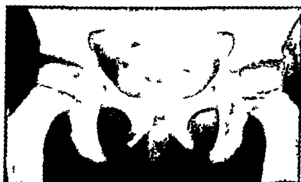


Fig. 13

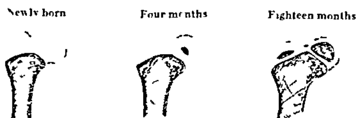
4 years and [illegible] months after birth

Case II. A slight varus deformity can still be seen with some broadening of the neck and metaphysis.

contrasting with the X rays which does not show any diaphyseal fracture but a dislocation lateral and upwards of the femoral shaft in relation to the acetabulum Calcification in the haematoma callus and periostal separations are early confirmatory signs on the radiograms

TREATMENT

The cases reported in the literature have been treated on different lines In some cases treatment has been like in our Case I positioning in abduction with—or without—traction In other cases traction has been established in vertical direction with the hip flexed Early results have been more or less satisfactory in both groups More than two years observation has not been reported in the literature The initial reduction of the fracture separation in our case was not very good and a varus deformity and a backwards-open angulation of the grown neck of the femur developed in a similar way as in Case II where no treatment was given *Harrenstein*s experiments accordingly indicates that the separation between the upper epiphysis and the diaphysis of the femur in the new born is followed by a displacement of the epiphysis in a similar way as in adolescent coxa vara ("slipped epiphysis) The "upper fragment displaced however will be of different size according to the age Fig 14 indicates the position of the epiphyseal plate in the new born distal to the trochanter major and proximal to the trochanter minor so that only the medial part of the neck in relation to the minor trochanter is ossified and in osseous connection with the diaphysis During further growth trochanter major and the head of femur are separated from the collum by a joint epiphyseal plate First around the age of two years isolated epiphyseal plates for the trochanter major and the head of the femur are established



(After *Trueta J B J S* May 1957)

Fig 14

Position of the epiphyseal plate in the upper end of femur at different ages



Fig 12
1 and a half year after birth
Case II Broadening of the neck and metaphysis with some varus retroversion deformity



Fig 13
4 years and 2 months after birth
Case II A slight varus deformity can still be seen with some broadening of the neck and metaphysis

born (1955) the lesion has not been found among 800 fractures on 100 000 births Based upon the literature *Thyge Madsen* reports that the lesion is rare even more infrequent than the traumatic separation of the lower femoral epiphysis One can presume that the lesion concerned very seldom is diagnosed but it is questionable whether the lesion is so rare as the literature suggests It is possible perhaps even likely that a fracture separation in the upper femoral epiphyseal plate sometimes is overlooked due to minor displacement and quick recovery of function It is suggested that cases met with later in childhood of monolateral coxa vara with no gross structional alterations of the collum or around the epiphyseal subcapital plate might have been of traumatic origin during birth

SUMMARY

Two case histories of traumatic separation of the upper femoral epiphysis during delivery are given Problems of diagnosis treatment and incidence of the lesion are discussed

RESUME

Il est donné l'histoire de deux cas de separation traumatique de la partie superieure de l'epiphyse femorale durant la delivrance Les problèmes du diagnostic du traitement et de la frequence de ces lesions sont discutes

ZUSAMMENFASSUNG

Zwei Krankengeschichten von traumatischer Abtrennung der proximalen Femurepiphyse wahrend der Geburt werden gebracht Probleme der Diagnose der Behandlung und des Vorkommens dieser Beschadigung werden besprochen

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From the Norfolk and Norwich Hospital England

ISCHIOFEMORAL "V" ARTHRODESIS OF THE HIP JOINT POSTERIOR APPROACH

By

R C Howard

Ischiofemoral "V" Arthrodesis of the hip joint was originally described by *Brittain* and used mainly for osteo arthritis A long Smith Petersen nail is used to fix the joint and an infra articular ischio femoral bone graft inserted *Brittain* kindly allowed me to make a preliminary report on the short term results in 37 patients at the Spring Meeting of the British Orthopaedic Association in 1950 In this series there was an 82 per cent rate of fusion of the graft which was considered sufficiently encouraging to continue using this method and between June 1948 and January 1955 the operation was done 123 times at the Norfolk & Norwich Hospital

It was possible to review the late results in 105 of these 123 patients and of these 95 had satisfactory bony union of the graft indicating a 90 per cent rate of bony fusion One patient had a satisfactory clinical result but fusion was not confirmed by recent X rays Four patients had established non union

One advantage of this type of arthrodesis where knee bending is encouraged early is that stiff knees do not occur 75 per cent of the patients regained full movements of the knee joint and the remainder regained at least 90 of flexion

The problem of backache must be mentioned as some Surgeons consider it a contra indication to fixation of the hip joint After reviewing these 105 patients I found that if mild recurrent low backache was present before the operation it often improved or disappeared once the deformity had been corrected and the hip rendered stable and painless Sometimes backache persisted but most patients considered it a minor disability I consider that lumbar backache with radiological signs of osteo-arthritis of the lumbar spine is not a contra indication to arthrodesis of the hip

COMPLICATIONS

The two most frequent complications in this series were —

1. *Fracture of the femur at the site of insertion of the graft.* This occurred in fourteen patients as a result of torsion or angulatory strains at varying times after operation.
2. *Fracture of the bone graft.* This occurred fourteen times. The fracture consisted of a crack and was always due to an injury or fall occurring during convalescence. Eleven of these crack fractures joined up rapidly, three with enlargement of the graft. Two fractures formed a fibrous union with good clinical results. One graft absorbed and a further graft was inserted with a successful result.

Sciatic Palsy

The sciatic nerve has been damaged twice. In spite of exploration and removal of the nail one patient is left with a permanent total sciatic nerve palsy. The other patient made a partial recovery but has weakness of dorsi flexion of the foot and has to wear a toe raising splint. Clearly this is by far the most serious complication and in my opinion one sciatic palsy is one too many.

The analysis of the results in these 105 patients made it clear that this was a successful operation giving bony fusion of the ischiofemoral graft in 90 per cent of patients. The most serious complication of sciatic palsy appeared to be under the control of the Surgeon if the operative approach to the hip joint was altered. This dreadful hazard could be eliminated by seeing the sciatic nerve and retracting it away from danger.

Because of this in 1956 I began to do the operation from behind with the patient lying prone (Fig. 1). Through a postero-lateral incision I was able to see the sciatic nerve and retract it. Soon certain other advantages became apparent. Correction of the common deformity of external rotation was made possible by dividing the posterior capsule, a correction which is impossible through the lateral approach. Division of the ilio-psoas tendon was still possible if this proved necessary as the lesser trochanter lies posterior to the inferior part of the femoral neck. Under direct vision the bone graft could be steered into the ischium without any doubt about its position in bone, whereas with the original technique there was often difficulty in obtaining adequate lateral radiographs in obese patients and sometimes the graft did not

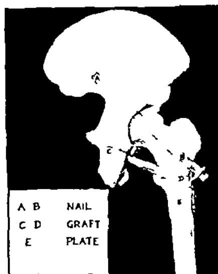


Fig 1

Posterior view of specimen of right hipjoint and pelvis on which this arthrodesis has been done



Fig 2

R li grap h of left hip joint in man aged 40 two ears after peration with sound ischi femoral bon unin

enter bone or its position was equivocal The muscle splitting postero-lateral approach caused less bleeding than the muscle cutting lateral approach and blood transfusions were seldom necessary (Fig 2)

A three hole plate could be attached without difficulty to the outer end of the nail thereby preventing a fracture of the femur at the site of insertion of the graft though I agree that this can be done equally well through a lateral incision

Operative Technique

Under a tourniquet with the patient lying on his back a 5 long graft is taken from the antero medial shoulder of the tibia Any adduction deformity is corrected by division of the origin of adductor muscles after which the patient is turned over face downwards

The skin incision extends from the posterior superior iliac spine obliquely downwards and outwards to the greater trochanter and then downwards along the femur for five inches The underlying fibres of the gluteus maximus are divided and split and the incision extended down the lateral aspect of the upper femur The sciatic nerve is found *and retracted medially revealing the posterior aspect of the hip joint* ischium pelvis and greater trochanter At this stage the posterior capsule or the ilio-psoas tendon can be divided further to correct deformity before the joint is fixed Under direct vision a 30 cm guide wire is inserted from the lateral aspect of the greater trochanter through the upper posterior part of the neck of the femur into the femoral head and on into the pelvis At this stage an antero-posterior X ray is taken to check the position of the guide wire and if it is satisfactory a nail of the appropriate length is driven over the guide wire into the pelvis to fix the hip The guide wire is then removed

One inch below the site of insertion of the nail a hole is drilled through the outer and inner cortices of the femur into the ischium This drill track is enlarged with successive drills until there is a track a half inch in diameter The tibial bone graft is pointed and driven along the track through the femur into the ischium This produces sound three dimensional fixation of the hip The outer end of the graft is trimmed a three hole plate applied and the wound closed

Post Operative Care

The patient is encouraged to bend the knee over the side of the bed as early as possible usually three or four days after the operation This

is important as a means of obtaining early full movements of the knee One joint has been fixed and therefore the patient must rely on the adjacent joint being fully mobilized

The stitches are removed at two weeks and the patient is allowed up on crutches at three weeks

Discussion on Operative Technique

Between January 1956 and December 1961 I have used this technique in 23 patients and in reviewing the results I have been convinced that this approach has certain advantages

There has been no damage to the sciatic nerve The inner end of the bone graft has always been in bone Deformities have been easier to correct and therefore a more ideal position of arthrodesis has been obtained *In none of them has a fracture of the femur occurred* As in the original series mentioned above there was a high rate of ischio femoral bony fusion and all 23 patients obtained radiological ischio femoral fusion one patient developing intra articular fusion as well All patients regained pre operative range of movements of the knee

Unfortunately there is one complication which has not been avoided by this method this being a stress fracture of the bone graft as in the original series and it still seems to occur because of the angulatory strains before the graft has become vascularized and strong The danger period is about ten weeks after the operation and perhaps a short hip spica might prevent this tiresome though not serious complication

In this series the graft sustained a stress fracture in 4 patients in the first three months Three joined up solidly without immobilization or special treatment The fourth failed to unite but the patient gained intra articular fusion which was satisfactory

Mechanical failure of metal fatigue in the bending of metal nails has occurred but this does not seem to affect the end result and is usually discovered by chance on the radiograph which is taken at intervals after the operations In this series the nail has bent a little in three patients and cracked in three patients but this made no difference to the sound bony fusion of the graft Recently I have designed some stouter Trifin nails made of Titanium which may prove to be stronger than the original stainless steel S M O nails and thereby prevent this fault

One patient developed a swollen leg from deep venous thrombosis a complication which unfortunately can occur after any major operation on the hip joint

CONCLUSION

This is a small series but I feel justified in publishing the results for two reasons Firstly the indications for arthrodesis are diminishing and one has to wait longer to obtain the larger figures mentioned in the original series Secondly this posterior approach for ischiofemoral V arthrodesis has made the operation not only easier but less hazardous and my experience of having done the operation 63 times through the lateral approach endorses this view

Arthrodesis is only a partial solution to the problem of unilateral osteo arthritis of the hip joint but it cannot deteriorate as an arthroplasty can and its chief merit is its permanence The patients can be discharged once bony fusion has taken place and I believe it will always have a place in the treatment of arthritis of the hip joint until an operation is found which produces a permanently painless stable mobile hip joint

My experience with ischiofemoral V arthrodesis has convinced me that when an arthrodesis is indicated this is a relatively sure way of achieving the desired result with a high rate of bony fusion of 95 per cent

SUMMARY

1 An account of a new posterior approach to the operation of ischiofemoral V arthrodesis designed to avoid certain complications occurring *in the original series of 105 patients operated on* between 1948 and 1955

2 A review of the results of 23 patients operated on between 1956 and 1961 by the new posterior approach

RESUME

1 Compte rendu d une nouvelle approche posterieure dans l operation de l arthrodese ischio fémorale « V » designee comme permettant d eviter certaines complications constatees dans une serie de 105 malades operes entre 1948 et 1955

2 Examen des resultats obtenue chez 23 malades operes entre 1956 et 1961 par la nouvelle approche posterieure

ZUSAMMENFASSUNG

1 Ein Bericht uber einen neuen ruckwartigen Zugang bei der ischiofemoralen V" Arthrodese der entworfen wurde um gewisse Komplika

tionen die bei der ursprunglichen zwischen 1948 und 1955 operierten Reihenfolge von 105 Patienten auftraten zu vermeiden

2 Eine Übersicht der Ergebnisse bei 23 mittels des neuen rückwärtigen Zuganges in den Jahren 1956 bis 1961 operierten Patienten

ACKNOWLEDGEMENTS

I am grateful to the followings Surgeons for having allowed me to follow up their cases Mr S W Davidson Mr A B King Mr J G Taylor

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From the Dept. of Paediatrics (Head: Prof. B. Vahlquist) and the Dept. of Orthopaedics (Former head: Prof. Carl Hirsch), University Hospital of Uppsala, Sweden

RESECTION OF THE OBTURATOR NERVE IN THE TREATMENT OF ADDUCTOR SPASTICITY IN CEREBRAL PALSY

By

BENGT HAGBERG[1], CARL HIRSCH and MONICA STERN[1]

INTRODUCTION

Spasticity of the hip adductors is a common disability in cerebral palsy. Adduction of the thighs and scissoring of the legs interfere with balance, gait and sometimes even with physical care of the patient. Coxa valga and dislocation of the hip are not infrequently observed, especially in elderly patients. In the treatment of this deformity various surgical procedures have been suggested, but their value has been open to considerable doubt. Favourable reports during the first decade of this century were for a long time virtually ignored and as late as 5–10 years ago every form of operative treatment for adductor deformity was strongly criticized in many centres for cerebral palsy. Surgical procedures seem to have been discredited mainly for the following two reasons: first, because operations were previously performed on a purely mechanical basis instead of being based on careful neurological, functional and developmental studies in each particular case, and secondly, because the necessity of intensive preoperative and postoperative physical training was neglected. This paper presents an analysis of a follow up study based on uniform evaluation of a clinical material before and after complete intrapelvic resection of the obturator nerve. Special emphasis has been placed on *neurological classification*, analysis of motor function before and after surgery, developmental aspects of motor and mental abilities and studies of undesirable side effects with regard to their character and extensiveness.

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HISTORICAL REVIEW

A functional disorder caused by spasticity of the hip adductors was early recognized as a very localized condition. Surgical intervention in order to relax the spastic muscles therefore seemed to be a procedure which justified therapeutic trial. In principle one of the following three ways was chosen to attain this goal:

1) Resection of muscle insertion: adductor tenotomy.
2) Interruption of impulses from the periphery stimulating muscular activity: division of posterior nerve roots.
3) Resection of the nervous supply to the adductor muscles: peripheral neurectomy.

Tenotomies were practiced during the late nineteenth century. Surgical procedures involving nerve elements were designed shortly before the first world war.

Foerster's operation (1908) comprises laminectomy and division of several posterior nerve roots. The results have been considered poor. The operation is practically abandoned and of little therapeutic interest.

Stoffel (1910) is generally credited with the idea of peripheral nerve resection. However *Lorenz* (1891) and *Lauenstein* (1892) were the first to perform partial neurotomies together with tenotomies in spastic hip adductors. The procedure was extrapelvic. Intrapelvic extraperitoneal nerve resections were suggested by *Henschen* (1913) and *Selig* (1919). Their methods were considered to be modifications of the ideas of *Lorenz* and *Stoffel*. The intrapelvic technique became popular for some time but was soon considered too radical. It was stated by *Albee* (1919), *Foerster* (1922), *Bade* (1922) and *Silfverskiöld* (1924) that the results were no better than with extrapelvic approaches. It was also pointed out that the procedure held a risk of excessive muscle relaxation leading to abduction contractures.

The lack of adequate analytical studies of clinical material, evaluated on a uniform basis both pre- and postoperatively, led to controversial opinions as to the value of peripheral nerve surgery. *Albee* (1919), when discussing nerve sections in his textbook, wrote that they occasionally give satisfactory results, but are not uniformly practised in spastic paralysis. Negative as well as positive experiences have alternated in various reports: *Carrol & Craig* (1951), *Barnett* (1952), *Silver* (1957), *Phelps* (1957), *Banks & Green* (1960) and *Pollock* (1962). *Phelps* (1957) made a remarkable statement: "neurectomy of any type has no

permanent value in the treatment of cerebral palsy, thus ignoring the careful and positive report of *Stoffel* (1912). When reading *Lindeman's* recent textbook (1963), one arrives at a far more encouraging conclusion. Obturator nerve resection is said to decrease the spasm in the adductors in an exceptional way, especially in children of 4–6 years of age. The operation eliminates the scissoring gait and creates conditions under which the child can learn to walk.

SURGICAL PROCEDURE FOR INTRAPELVIC OBTURATOR NERVE RESECTION

We used the surgical technique devised by *Loeffler* (1921) and *Gochl* (1925). When the operation involved one side only, a longitudinal incision along the border of the rectus abdominis muscle was the usual practice. In bilateral neurotomies Pfannenstiel's square rectangular cut just above the symphysis was preferred. After opening of the anterior part of the rectus sheath the transversal fascia and the peritoneum were moved aside bluntly. With the fingers palpating through the soft connective tissue down to the obturator foramen it is easy to find the obturator nerve as a dense, round, mobile chord. A blunt hook is put around the nerve and electric stimulation is applied to check adductor muscle activity. Two or three centimetres are then resected. The wound is closed. As a rule there is no or very little bleeding. The child is often ready to be started on exercises by the next day. It is indeed a minor and very simple procedure, always well tolerated by the patient. It affects the child much less than an extrapelvic operation and requires no plaster immobilization.

THE ANATOMICAL BACKGROUND OF THE OPERATION

The adductor muscles are innervated in several ways and some muscles are doubly innervated. Even total resection of the obturator nerve therefore causes only partial denervation of the adducting muscles. They will become weaker but still have part of their function left.

The obturator nerve originates from L2, L3 and L4. Just before entering into the obturator foramen and the channel the nerve is divided into two branches. The anterior supplies adductor longus, adductor brevis and gracilis. The posterior, shorter branch goes to obturator externus and adductor magnus. Adductor magnus is also innervated from the sciatic nerve and the pectineus muscle is supplied by the femoral nerve.

INDICATIONS FOR SURGERY

In order to arrive at a proper classification of cases, acceptance of patients for operation was determined by the following qualifications:

1) Each case should be exactly classified with regard to neurological type and degree of disability.
2) The developmental and functional level of motor activity ought to be known in detail.
3) The aim of the operation in each particular case should be defined.
4) The patient's possibilities to benefit from the surgical procedure should be seriously considered.
5) The operation must be preceded—and succeeded—by carefully planned and intensive periods of physical training.

The main indication for operation has been a desire to achieve a better gait or to improve the child's chances of learning to walk, or, if walking was not considered possible, to gain a more stable way of sitting. In a few cases surgery was performed with a view to facilitating physical care of the patient, since pronounced adduction contractures caused sores in the groin. In a few other cases the operation was mainly performed to prevent hip dislocation when subluxation was already a fact.

CLINICAL MATERIAL

The clinical material consists of 41 cerebral palsy patients from 1–21 years of age. Patients operated upon after the age of seven had not been under our care before that age.

The distribution in age groups and types of cerebral palsy syndromes is illustrated in Table 1, indicating the evaluation before surgery. Most of the cases, 28 out of 41, had hypertonic diplegia of varying severity. The degree of preoperative deformity or disability is illustrated by the different groups in Tables 3, 4 and 5. The time of follow up after operation is found in Table 2. In roughly 15 per cent the period of follow up was less than two years, but in no case less than one year. All patients belonging to group I (Table 1) had received from several months to years of intensive preoperative physical therapy. All of them were also given postoperative physical training over a period of months or years. Preoperative treatment had only been advised in a few selected cases from group II (Table 1), while most of these children, especially

those with microcephaly and severe tetraplegia were considered too mentally retarded to co-operate.

TABLE 1

General indication, clinical diagnosis and age at operation in 41 cases

General indication for operation	Clinical diagnosis	Age in years at operation						
		1-3	3-5	5-7	7-9	9-11	>11	Total n
Group I								
Improved	Hypertonic diplegia	6	8	6	2	1	5	28
motor function	Hypertonic hemiplegia					1		1
	Dystonic tetraplegia			1	2			3
Group II								
Mainly facilitation	Severe tetraplegia							
of physical care	in metally retarded	2	1	2			4	9

TABLE 2

Observation time for the clinical material (41 cases)

Clinical diagnosis	Time of follow up in years				
	1-2	2-3	3-4	4-5	>5
Hypertonic diplegia	4	7	7	7	3
Hypertonic hemiplegia		1			
Dystonic tetraplegia	1				2
Severe tetraplegia +					
mental retardation	2	3	1	3	
Total no. case	7	11	8	10	5

The operation was performed on both sides in 34 patients and on one side in 7 (hypertonic hemiplegia 1, dystonic 1, hypertonic diplegia 5).

During the period of follow up other surgical interventions have been undertaken in 15 cases: release of the gastrocnemius in 11, transposition of the posterior tibial tendon in one and transposition of the biceps femoris in 4 cases. Adductor tenotomy complementary to obturator nerve resection was later performed in one case.

RESULTS

The results of surgery have been analysed during two different post-operative periods:

1) the immediate effect obtained within the first weeks of operation
2) the late results after 1–7 years of follow up.

This way of examining the patients offers a more reliable method of reaching an opinion about the surgical procedure as such, since both developmental factors and other concurrent forms of treatment may interfere with the picture of late results.

The resection of the obturator nerve immediately breaks the reflexes to the spastic hip adductors but also affects the spasticity at large. This immediate effect on muscle tone in the legs has been illustrated in Table 3. The table further shows that 4 of the 41 cases displayed obvious adductor hypotonia and insufficient adductor function during the early postoperative period. Slight symptoms of insufficiency occurred in many other cases the first days after surgery, but then decreased considerably.

TABLE 3

Immediate effect of obturator neurectomy on muscle tone in the legs

Degree of adductor spasm	No. of cases	General decrease of hypertonus	Adductor hypotonia with insufficiency
Severe			
(Scissoring of legs in supine at rest)	17	14	3
Moderate			
(Scissors gait)	15	14	1
Slight			
(Walking with adducted and slightly flexed knees)	9	9	0

A very surprising early result of the operation was the immediate improvement of internal rotation and flexion in the hip joint and the favourable effect on drop foot. Mostly, however, such improvement was of a minor degree and often only temporary.

One of the great advantages of the operation was without doubt the clearly improved way of sitting. This was true for most of the cases. The results in this respect can be seen in Table 4. The operation weakens the otherwise strong extensor thrust reflex which forces the child backwards and interferes with balance. With improved sitting ability the child's mental development was found to gain favourably and often to a high extent. This was seen especially during the early postoperative period, mainly among our youngest children.

Astonishing was the rapid improvement in crawling and walking. Table 5 gives the results.

TABLE 4

Immediate effect of obturator neurectomy on the sitting position within the first few weeks in 37 cases (4 microcephalics excluded)

Capability in sitting posture	Before neurectomy	After neurectomy	Acquired capability
Tailor's seat	23	35	12
With abducted and extended legs	1	26	25
Steady on chair with support	20	31	11
Steady on stool without support	14	27	13

TABLE 5

Immediate effect of obturator neurectomy on creeping and walking ability within the first few months in 37 cases (4 microcephalics excluded)

Motor capability	Before neurectomy	After neurectomy	Acquired capability
Ability of holding crawling position	22	34	12
Crawling on hands and knees	16	25	9
Walking with walking aids	10	22	12
Independent walking	10	15	5

TABLE 6

Desired effect compared to actual results with obturator neurectomy at follow-up examination in 41 cases

Clinical diagnosis (dominating syndrome)	For improved standing walking		For improved sitting besides walking		For improved sitting posture only		To easier daily care	
	Desired	Actual	Desired	Actual	Desired	Actual	Desired	Actual
Hypertonic diplegia	25	23	25	25	3	3		
Hypertonic hemiplegia	1	1						
Dystonic tetraplegia					3	3		
Severe tetraplegia in mentally retarded					5	5	4	4

Table 6–9 illustrate the late results. In Table 6 a comparison is made between the desired and achieved conditions. It can be seen that only rarely did the operation fail.

The basic reason for operation was to arrive at a better balance between adductor and abductors. Results in this respect are shown in Table 7, where the clinical material has been divided according to the

TABLE 7

Result of obturator neurectomy on adductor/abductor balance at follow up examination

Degree of adductor spasm	No. cases	Satisfactory improvement	Partial improvement	Unimproved adductor spasm	Improvement with adductor weakness
Severe (Scissoring in supine at rest)	17	5	9	0	3
Moderate (Scissors gait)	15	11	4	0	0
Slight (Walking with adducted and slightly flexed knees)	9	8	1	0	0

includes the only case where adductor tenotomy was made in addition to obturator neurectomy

TABLE 8

Effect of obturator neurectomy on other spastic leg deformities of the 28 cases with hypertonic diplegia

Type of spastic deformity	Present before operation in no. cases	Useful improvement	Partial improvement but unsatisfactory	No improvement	Deterioration
Tip toe gait	25	0	13	12	0
Internal rotation of legs	26	7	14	5	0
Hip joint flexion	27	12	10	5	0

TABLE 9

Undesirable results of obturator neurectomy at follow up examination of the 28 cases with hypertonic diplegia

Degree of motor handicap	No.	Remaining scissors gait (but improved)	[illegible] insufficiency in walking	[illegible] insufficiency in crawling	Hip joint instability
Independent walking	14	1	0	0	0
Walking with sticks	2	0	0	0	0
Walking with saw horse crutches	4	1	0	0	2
Walking only in spec. walker	8	5	0	4	3
Total	28	7	0	4	5

Three identical patients in these two groups

degree of preoperative adductor spasm. The best results were found—not unexpectedly—in those children where the adductor spasm was less from the beginning. Table 8 presents the end results for other spastic deformities in the lower extremities. These results seem to be better than they really are, and are probably influenced by other operations performed during the follow up period.

Undesirable consequences have been collected in Table 9. Scissoring gait remained in 7 of the 28 cases with hypertonic diplegia. In about ¼ of this material even a complete obturator nerve section was not enough to overcome adductor dominance in walking. Appreciable residual adductor insufficiency was observed in but a few cases, mostly affecting only certain activities. Not in a single case however did this weakness in the adductors affect the upright position or the gait. When walking, all of these patients still were scissoring. The weakness in the adductors would show up when the children were crawling. This was especially marked for the 4 most seriously affected cases in the diplegia group. These four children also had marked instability of the hips. Although this condition was apparent before the operation, the obturator nerve resection had made it worse. All these children did however show improvement in sitting. The parents and the physiotherapists felt that the children had gained from the operation in the long run, mainly with regard to many physical and mental activities. It was obvious that these cases with insufficient adductors represented a special type where the component of mucsular weakness dominated the spastic component. The rest of the cases where the effect of surgery was insufficient, represent the other extreme, with the spastic component strongly dominating.

DISCUSSION AND CONCLUSIONS

Our experiences have led us to conclude that this operation is easily overcome by the child and obviously very effective. In well classified and selected cases even small children will benefit. The surgical treatment should be combined with adequate physical training both before and after operation. After the operation the child should be brought back to the milieu where it has been trained preoperatively and where the physiotherapist is well aware of the problems for which surgery was suggested.

The operation is particularly suitable for cases with hypertonic diplegia of a moderate to pronounced degree. It also has its advantages

in different forms of severe tetraplegia where permanent adductor dominance causes difficulties in sitting, lying or physical care of the patient. *In most cases of dystonic cerebral palsy combined with more or less distinct athetoid shifts, operation should be avoided.* In these cases the adductor spasm is never permanent; it is induced through changes in posture and is always variable.

One strong reason for suggesting operation in early childhood is the developmental aspect. The effect on the extensor thrust reflex, the negative influence of which is broken or markedly decreased by the operation, opens a way of utilizing motor and intelligence potential. These developmental conditions justify surgery even if experiences from a longer follow-up period than ours would show that the results may not persist into adult life.

In summarizing the effects of obturator nerve resection on motor function, it can be stated that:

1) *For walking and standing ability* the operation was found to give satisfactory results in all children with spastic diplegia of a slight degree. Instability of the hip joints occurred in a few of the severe cases with pronounced muscle insufficiency, but the chances of improvement would in these cases not have been any better without an operation. In none of the cases was adductor insufficiency present in the upright position. A positive Trendelenburg sign was not found to contraindicate surgery.
2) In patients with hypertonic diplegia the operation was always beneficial *for sitting ability*, often to a surprising degree. Negative effects on this function were never observed. This indication sometimes also holds true for severely disabled patients with the dystonic type of cerebral palsy, mainly those with concurrent spastic signs (ancle clonus, positive Babinski etc.). One must accept that in these cases standing and walking cannot be expected to improve. Sometimes, however, they do.
3) *For crawling and standing on the knees* improvement was not infrequently achieved. This was especially true in cases with strong spastic muscles. They often learned to crawl by alternating hands and knees, impossible to them before the operation. When there was a more pronounced general weakness of the muscles, insufficiency of the adductors was sometimes apparent in crawling, resulting in a swimming type of movements. However, these children could never crawl at all before the operation. In addition

the adductor weakness was not seldom found to be temporary and partial.

4) *For better physical care* obturator nerve resection is justified in many instances where severe mental retardation is combined with tetraplegia. Microcephalic patients do not seldom develop pronounced adductor spasticity, prohibiting washing and clothing.
5) *Hip subluxation or dislocation* is not unusual in these mentally retarded cases. The operation should be performed before the deformity ends in a fixed dislocation.
6) When the hip *abductors were very weakened* resection of the obturator nerve was sometimes the only way of getting the hip joint into active abduction movements. This experience is an additional indication for surgery early in childhood.

SUMMARY

A follow up study was made of 41 cases with cerebral palsy who had been treated with intrapelvic resection of the main trunk of the obturator nerve for disabling spasticity of the hip adductors. The mean age at operation was 5 years. The time of follow up was 3–4 years on the average. Bilateral operation was performed in 34 cases. Twenty eight of the cases had spastic diplegia, 1 spastic hemiplegia, 3 dystonic tetraplegia, and 9 concerned a group of mentally retarded with severe tetraplegia. The operation was found to be of great value in well classified and selected cases. The indications are discussed. Special emphasis is laid on careful neurological, functional and developmental studies preoperatively, and on the necessity of intensive pre- and postoperative physical training.

RÉSUMÉ

Une étude complémentaire a été faite sur 41 cas de paralysie cérébrale traités par résection intrapelvienne du tronc principal du nerf obturateur pour invalidité spasmodique des adducteurs de la hanche. A l'époque de l'opération, l'âge moyen était de 5 ans. La période d'observation a été en moyenne 3–4 ans. Une opération bilatérale a été pratiquée dans 34 cas. 28 des malades souffraient de diplégie spasmodique, un d'hémiplégie spasmodique, 3 de tétraplégie dystonique et 9 appartenaient à un groupe de retardés mentaux avec tétraplégie grave. On a trouvé que l'opération était de grande valeur dans les cas bien classifiés et bien sélectionnés. Il est discuté des indications. Il est recommandé en

ticulier de proceder avant l operation a des etudes minutieuses de at neurologique fonctionnel et aussi du developpement du malade est insiste sur la necessite d un traitement d entrainement physique nsif avant et apres l operation

ZUSAMMENFASSUNG

Eine Nachuntersuchung von 42 Fällen mit cerebraler Parese die tels intrapelviner Resektion des Hauptstammes des n obturatorius gen verkruppelnder Spastizitat der Huftadduktoren behandelt wor waren wurde vorgenommen Das Durchschnittsalter zur Zeit der ration war 5 Jahre Der Zeitpunkt der Nachuntersuchung war im rchschnitt 3–4 Jahre Doppelseitige Operation wurde in 34 Fällen gefuhrt Achtundzwanzig der Fälle hatten spastische Diplegie 1 spa che Hemiplegie 3 dystonische Tetraplegie und 9 betrafen eine ppe von geistig Zuruckgebliebenen mit schwerer Tetraplegie In gut ssifizierten und ausgewählten Fällen erwies sich die Operation als r wertvoll Die Anzeigestellung wird besprochen Besondere Wert d auf eine sorgfaltige neurologische funktionelle und entwicklungs ssige Untersuchung vor der Operation und auf die Notwendigkeit er intensiven pre und postoperativen korperlichen Übungsbehand g gelegt

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THE TREATMENT OF CLUB FOOT AND ITS RESULTS

A Follow-up Study

By

HELGE T. SEMB

There are several theories as to the etiology of *tapiles equinovarus*. An early one is that in which the deformity is considered to be conditioned by a mechanical misplacement of the feet of the foetus *in utero* with subsequent contractions of the soft parts, fixing the foot and giving it the characteristic *equinus*, *varus* and *adductus* components after partus (3). Particularly in recent years, however, several authors, such as *inter alia Bechtol & Mossman, Flinchum, Fredenhagen, Hirsch* and *Stewart* (2, 4–6, 13), have investigated club-feet and have pointed out anomalies in ligaments, muscles and tendon attachments, which might explain the deformity. Nothing certain is yet known, however, as to whether these anomalies arise on a genetic basis or as a result of some harmful influence on the foetus during a sensitive stage in its development. On the basis of these findings many authors have therefore adopted the view that the cause is a non-physiological functioning of certain muscles, tendons and ligaments in the foot, by which the static and dynamic characteristics of the foot are altered, with subsequent secondary deformations of the skeletal structure.

As regards the general principles of treatment for congenital club foot, the majority of authors are today fairly unanimous. Attempts are made to improve the anatomical conditions at as early a stage as possible by means of repeated manipulative measures and subsequent fixations by various methods. Only when the corrective measures taken in hospital do not prove to be sufficiently effective or in the case of a relapse are operative measures resorted to. When the Orthopaedic Clinic at Uppsala came into being in the autumn of 1955, treatment at first followed the general principles mentioned above. However, as there was dissatisfaction with the results of this treatment, as in other

quarters where treatment of club feet has been undertaken on account of the many cases which did not yield to therapy and which relapsed new therapeutic methods were tried after a year or so Attention was principally centred on the medial part of the foot and a number of surgical explorations were made medially across the tarsus with resection of the ligamentum deltoideum *Hirsch* (6) has previously described this technique The present investigation has been carried out primarily to get an idea of the results of the treatment of club foot worked out in the last few years at the Uppsala Clinic

MATERIAL

Between November 1955 and May 1962 70 patients with pure *talipes equinovarus congenitus* were registered at the Clinic Thus this number does not include cases which showed in addition to club foot other malformations such as arthrogryposis *luxatio coxae congenitus* aplasiae finger anomalies etc

The investigation includes the club foot patients who were treated primarily or secondarily during the first few years of life at the Uppsala Clinic and hence not the cases which received primary treatment at another place and for various reasons came to Uppsala for further treatment several years later The material includes 31 patients all born after January 1954 Of these 30 came to the follow up examination Twenty (67 per cent) of those examined were boys and 10 (33 per cent) girls In 12 patients there were bilateral deformities in 11 in the right foot and in 7 in the left foot so that the total number of club feet was 42 (Table 1)

The observation period i e the period between the beginning of the treatment and the follow up examination varied between 2 and 8 5 years and was on the average 4 3 years

TABLE 1
Distribution by sex and lateral localization of the deformity

	Boys	Girls	Total
Bilateral	7	5	12
Right sided	7	4	11
Left sided	6	1	7
Total	20	10	30

METHODS

At the examination the parents were questioned as to the possible occurrence of *pes equino varus* in their nearest relations The circumstances of the actual pregnancy were also investigated especially with regard to possible virus infections supply of known teratogenic drugs or the influence in other respects of possible factors producing malformations during the first few months of pregnancy

The results of treatment were partly assessed by ordinary *clinical* examination after which it was possible to divide the material into good fairly good and poor cases In addition all the feet were examined by radiography

1 *Clinical Examination*

(a) *Good" result* No lameness dorsal flexion in the talocrural joint to at least 0 plantar flexion to at least 30–35 calcaneus in medial position between pronation and supination possibly with some range of movement in either or both directions and a moderate degree of adduction of the forefoot to a maximum of 10

(b) *Fairly good result* Only a hint of lameness no dorsal flexion possibly *pes equinus* of up to 10 plantar flexion of between 25 and 30 a slight but clear supination of the calcaneus without any pronation from this position and an adduction of the forefoot of 10–25

(c) *Poor result* Inferior to (*a*) and (*b*) above

An ordinary dorso-plantar projection was used in the radiographic investigation in order to get an idea of the degree of inversion of the tarsus by recording primarily the relative positions of the talus and the calcaneus In inversion in the foot there is a reduced angle between the longitudinal axes of the bones mentioned owing to the fact that the talus is projected over the calcaneus (7 14) (Fig 1) An additional idea of the foot s degree of inversion was obtained by the so-called suro plantar projection described by *Kandel* (7) (Fig 2) *Kleiger & Mankin* (9) have also described a similar method

The material was divided into three groups with regard to age at the beginning of treatment Group I younger than 1 week (8 cases) Group II 1-3 weeks old (12 cases) Group III 3 weeks to 3 months old (10 cases)

The results of treatment were compared with the average fixation time in plaster of Paris between each redression in the various patients The results were also correlated to the length of the primary period of

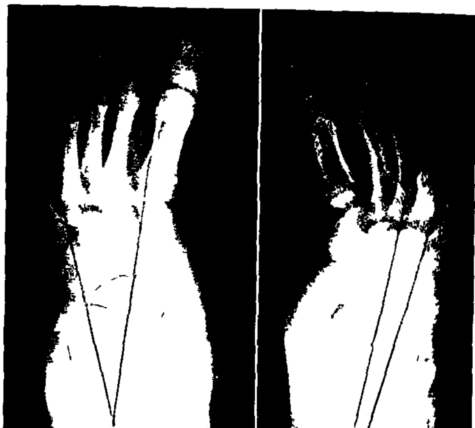


Fig 1

Dorso plantar X ray photograph Six year old girl with bilateral club feet The right foot clinically "fairly good" and the left foot "good" The angle between talus and calcaneus abnormally small bilaterally most pronounced in the right foot Naviculare displaced medially with reduced supporting surface toward the talus in the right foot Bilateral adduction of the forefoot most pronounced in the right foot

treatment By this period is meant the time during which the patient was treated with preliminary redressions and fixations up to the time when the deformity was considered to have been corrected and a beginning was made with a night splint Thus in difficult cases a surgical operation may also have been carried out during this period

The number of operations of various types was recorded and the results were analysed As regards patients who had been operated on several times the results of the follow up examination could accordingly be assigned only to the latest operation



Fig 2

Suro-plantar" X-ray photograph Four year old boy with right sided clinically "poor" club foot Left foot normal Both talus and calcaneus somewhat hypoplastic in the right foot Right calcaneus supinated Right talus lies cranially of the calcaneus whilst the left talus lies medially of the upper pole of the calcaneus Fibula is projected over the tibia on the right but not on the left side

RESULTS

Hereditary Occurrence

In a total of 12 cases (40 per cent) there was a congenital club foot deformity in the family These cases were distributed as follows (I in the same generation (brothers and sisters) 2 (II) in a direct line upwards (father) 1 (grandfather) 2 (III) collaterally (paternal uncle or aunt) 2 (cousin) 1 (more distant relations) 4

Pregnancy

One mother had fallen ill with "Asiatic influenza in the third or fourth month of pregnancy Another suffered a severe infection of the upper respiratory tract in the fourth month Both of them were treated with sulpha drugs and the lungs of the second were X rayed in connection with the infection Two mothers had slight haemorrhages in the

third month and one was threatened with a miscarriage in the fourth month One patient was born of a mother with diabetes who required insulin In this case partus was induced a month too soon but was otherwise unremarkable Consumption of thalidomide or other drugs with a known teratogenic effect early in pregnancy could not be proved in any of these cases Two of the patients had been born in breech presentation and the remainder in vertex presentation

Results of Treatment

The material has been collated in Table 2 No designates all the club feet in the 30 patients investigated These were graded as good fairly good and poor after clinical assessment by the method described above The results were good in 31 per cent fairly good in 43 per cent and poor in 26 per cent

Table 3 shows the results in Groups I II and III which have been defined in detail under Methods In each of Groups I and II 29 per cent were good and 57 per cent and 50 per cent respectively were fairly good Group III showed good results in 36 per cent The results in Groups I and II were poor in 14 per cent and 21 per cent respectively and in Group III 43 per cent

TABLE 2

Result at the follow up examination after clinical assessment

Result	Result of clinical examination			
	Good	Fairly good	Poor	Total
No	13	18	11	42
Per cent	31	43	26	100

TABLE 3

Result at the follow up examination compared with the child's age at the beginning of treatment

	Group I		Group II		Group III		Total	
	No	Per cent	No	Per cent	No	Per cent	No	Per cent
Good	4	29	4	29	5	36	13	31
Fairly good	8	57	7	50	3	21	18	43
Poor	2	14	3	21	6	43	11	26
Total	14	100	14	100	14	100	42	100

TABLE 4

Result at the follow up examination correlated with the length of the primary treatment period

Primary treatment period	Clinical result per cent			No
	Good	Fairly good	Poor	
0-3 months	33	40	27	15
3-6 months	25	50	25	16
Over 6 months	36	36	28	11

TABLE 5

Number of operations of various types carried out on the whole material

Type of operation	No
Achillotomy + possible capsulotomy	19
Achillodeltoideotomy	27
Transposition of tibialis post	8
Rotation osteotomy of tibia	7
Total	58

The average fixation times in plaster of Paris between each redression in the various groups with good fairly good and poor results turned out to be broadly speaking equal

The largest number of good results (36 per cent) had a long period of primary treatment (over 6 months) but even with primary treatment for at most 3 months the results were good in 33 per cent The frequency of "poor results was about the same irrespective of the length of the period of primary treatment (Table 4)

All except six of the club feet examined had been subjected to some form of surgical operation The number of operations of various types appears in Table 5 which shows a clear preponderance of achillodeltoideotomies The results of the various operations are shown in Table 6 In fixing a basis for these calculations regard was paid only to the latest operation carried out on the patient in accordance with the statement in "Methods above The percentage figures in the table show the best results following achillodeltoideotomies and tendon transpositions and the worst following achillotomy Of the six patients not operated on three were good and three "fairly good at the examination

More or less serious deviations from the normal picture were recorded

by X-ray in 40 (95 per cent) of the club feet investigated. Thus from the radiographical point of view only two (5 per cent) of them had been completely corrected.

TABLE 6

Result of follow-up examination after various types of operation

Result	Achillotomy		Achillo-tibialotomy		Tendon transposition		Rotation osteotomy	
	No.	per cent	No.	per cent	No.	per cent	No.	per cent
Good	–	–	7	28	1	25	1	20
Fairly good	1	50	10	40	2	50	4	80
Poor	1	50	8	32	1	25	–	–
Total	2	100	25	100	4	100	5	100

DISCUSSION

This follow-up study cannot be considered to reflect any finality as regards the treatment of club foot but would seem to be able to give some guidance as to certain principles in such treatment.

The material contains about twice as many boys (67 per cent) as girls (33 per cent), figures which are in good agreement with what other authors (5, 10–12) have found previously.

In 40 per cent of the patients there was club foot in the family. This is a strikingly high percentage and greatly exceeds, for example, Fredenhagen's result (14.5 per cent) (5). This difference compared with previous results can probably be largely ascribed to a chance accumulation asserting itself strongly in the present small material.

The attempt at an etiological analysis as regards the possible occurrence of teratogenetic factors during an early stage of pregnancy can scarcely be considered to have yielded any decidedly positive result. A single diagnostic X-ray examination of one mother in the fourth month of pregnancy probably cannot be assigned any teratogenic effect. The treatment of chick embryos with sulpha drugs has previously been reported to produce malformations (1) but the dosage was then so large that the mortality was 100 per cent. For this reason the short treatment of two mothers with therapeutic doses of sulpha drugs at an early stage of pregnancy cannot have played any part in the origin of the deformity. Nor can the slight haemorrhage noted in two women easily have had any teratogenic effect.

The results of treatment were "poor" in 26 per cent of the material

as a whole Thus there were satisfactory (good or fairly good) results in 74 per cent which broadly speaking agrees with the follow up studies of other authors (5 10 12)

Table 3 shows that the frequency of poor results increases the older the child is at the beginning of treatment Thus in the present investigation 14 per cent were poor and 86 per cent satisfactory in Group I (younger than 1 week at the beginning of treatment) The corresponding values in Group II (1–3 weeks old) were 21 per cent and 79 per cent and in Group III (older than 3 weeks) 43 per cent and 57 per cent There are accordingly greater chances of achieving satisfactory results with redressions and fixations initiated early on as has also been remarked by several authors (5 12)

It was not possible to show any great difference between patients with periods of primary treatment of different lengths as regards the result of treatment In this case however another factor viz the degree of initial deformity plays a part It was unfortunately not possible to map this out on the basis of the journal notes It may be considered as self evident that a moderate club foot can be corrected as well in a short period of primary treatment as a severe one in a longer period Most people engaged in the treatment of club foot find that the risk of relapse is greater when the primary treatment is concluded early However the doctor in charge of the treatment will often conclude the fixation in plaster of Paris relatively early in order to counteract atrophy of the calf and stiffness in the foot by functional treatment and he therefore generally attempts to strike a balance between the two requirements

Nineteen achillotomies (Table 5) were carried out in the whole material In 17 of these cases a further surgical operation was performed in the subsequent course of the treatment This seems to argue that in these cases unsatisfactory results were achieved with achillotomy However this is not the whole truth as it must be remembered that achillodeltoideotomy was performed in several cases chiefly for diagnostic purposes and then often after achillotomy had previously been performed perhaps with tolerably satisfactory results Achillodeltoideotomy shows the largest number of "good results However it is impossible in this small material to make any safe comparison between the results of the different types of operation especially as it was not possible to establish the degree of deformity which existed before the various operations As regards the achillodeltoideotomies which primarily yielded good results (6) relapses have been recorded in several

cases with tight scar formation medially across the tarsus So the problem of loosening the tight soft parts in the ligamentum deltoideum and its environment without postoperative scar formation seems still to be unsolved In order to achieve a permanent good result however it is important that the foot be fixed for a sufficiently long time after the operation This is in agreement with the good results reported by *Paula & Sulamaa* (11) after early modified Brockman operation with subsequent prolonged fixation For the present however better results are probably achieved with prolonged correction and fixation treatment

The radiographical examination may be regarded as a sensitive method of showing deviations in the normal anatomy of the foot In the present investigation there was more or less pronounced inversion in the tarsus in as high a percentage as 95 per cent In a large number of these radiographically unsatisfactory cases the results from the clinical point of view were good or fairly good In many intractable cases it is hardly possible to achieve a normal X ray picture with any form of therapy If however there are doubts as to whether a club foot has been corrected or not an X ray picture of the foot skeleton can give good guidance as to whether continued correction and fixation are necessary or not

A strikingly large number of the cases investigated had persistent more or less pronounced forefoot adduction One conceivable cause of this deformity is the fact that their night splints to a large extent only fixed the lower leg and foot without reaching up to the thigh for which reason the foot had some possibility of being adduced

The result of the investigation is not really satisfactory though it is largely in agreement with what other investigators have found (5 10 12) Relapses were very common even after the deformity seemed to have been completely corrected This was particularly the case if correction had been achieved as early as after 2–3 months of primary treatment To achieve a more permanent result fixation after initial redressions should consequently be continued for a long period perhaps up to a year However as so long a period of fixation in plaster of Paris produces pronounced calf atrophy and rigid feet it is desirable that a fixation material should be produced that *will also allow despite* the fixation a certain use of the feet and leg Experience also shows that it is very important to initiate therapy as early as possible

SUMMARY

A follow up study of a material consisting of 30 patients with a total of 42 club feet is presented The result was good in 31 per cent fairly good in 43 per cent and poor in 26 per cent There was a better result when treatment was initiated early The most successful operation was achillodeltoideotomy which in a number of cases however produced deforming medial scar contractions and relapses The radiographic picture showed more or less pronounced and persistent deformity of the foot skeleton in 95 per cent

The early initiation of redressions and corrections which should continue for several months and if possible result in a normal X ray picture must be considered to be important Only after this treatment is it possible to go over to night splints which should then reach up to the thigh In cases very resistant to therapy and in pronounced relapses operative measures may be resorted to

RÉSUMÉ

Le reexamen d un materiel d observation comptant 30 malades avec un nombre total de 42 pieds bots est presente Le resultat a eté bon dans 31 pour cent relativement bon dans 43 pour cent et mediocre dans 26 pour cent Le resultat a ete meilleur lorsque le traitement avait ete instaure tres tot L opération ayant le mieux reussi a ete l achillodeltoideotomie qui a neanmoins dans un certain nombre de cas provoque une deformation mediale des contractions cicatricielles et des rechutes Le tableau radiographique montre une deformite plus ou moins prononcee et persistante du squelette du pied dans 95 pour cent des cas

L entreprise precoce du redressement et de la correction qui doivent se poursuivre durant plusieurs mois pour arriver si possible a un tableau radiographique normal est consideree comme tres importante C est seulement apres ce traitement qu il est possible de penser aux eclisses la nuit celles-ci devant aller jusqu a la cuisse Dans les cas tres resistants a la therapie avec des rechutes prononcees il faut alors avoir recours egalement a une intervention chirurgicale

ZUSAMMENFASSUNG

Eine Nachuntersuchung eines Materials von 30 Patienten mit einer Gesamtanzahl von 42 Klumpfussen wird dargeboten Das Ergebnis war gut in 31 Prozent halbwegs gut in 43 Prozent und schlecht in 26 Prozent Ein besseres Ergebnis wurde erzielt wenn mit der Behandlung

fruhzeitig begonnen wurde Die erfolgreichste Operation war die Achillodeltoideotomie die jedoch in einer Anzahl von Fallen eine Deformierung mediale Narbenkontraktur und Rückfalle hervorrief Das Rontgenbild zeigte mehr oder weniger ausgesprochene und beharrende Verbildung des Fussskelettes in 95 Prozent

Der fruhzeitige Beginn der Redression und Korrekturen die wahrend mehrerer Monate fortgesetzt werden sollten und wenn moglich ein normales Rontgenbild ergeben sollten muss als wichtig angesehen werden Nur nach dieser Behandlung ist es moglich auf Nachtschienen die dann bis zum Oberschenkel reichen sollten uberzugehen In Fallen die sich gegenuber der Behandlung als sehr hartnackig erweisen und bei ausgesprochenen Rückfallen muss zu operativen Massregeln gegriffen werden

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From the Orthopaedic Hospital in Copenhagen

THE ACCURACY OF ORTHOROENTGENOGRAPHIC MEASUREMENTS

By

ERIK L. NORDENTOFT

During the past 20 years orthoroentgenographic methods have been widely employed for accurate measurement of lower extremity length in orthopaedic and paediatric clinics and in anthropometric studies. The method of measurement have been commonly accepted as completely reliable and attempts to evaluate the accuracy of the method in practical use do not seem to have appeared in the literature.

The accuracy of the measurements is of special interest in scientific evaluation of the results of operative procedures for correcting leg length inequalities. For practical purposes the term "anisomelia" devised by *Bertelsen* (1955) to cover the Anglo-saxon "inequality of leg length" will be used, as it is thought to be shorter, more precise and better suited for international use.

Errors in orthoroentgenographic measurement may arise from distortion due to inaccurate focusing over the ends of the measured bones. Film alterations due to shrinkage and to thermal and humidity expansion may play a role. Finally, complete immobility between the exposures and exactly identical positioning of the legs at serial examinations is indispensable for the comparability of the measurements.

Green, Wyatt & Anderson (1946) devised a method for orthoroentgenographic measurement. They compared their results of X-ray measurement to direct measurement in one leg post mortem. The tibial lengths were equal. The femur was 2 mm. shorter on the X-ray than the actual length.

Goldstein & Dreisinger (1950) described a spot orthoroentgenographic method, where each joint was exposed separately. The error due to distortion was computed to maximum 1.3 per cent. A mean error of 0.25 per cent by storage shrinkage was estimated. Humidity and thermal

expansion was negligeable. It exceeded 0.11 and 0.06 per cent respectively only in extreme cases.

These investigators, however, do not pay attention to the most probable sources of error, namely movements between the single exposures in each examination and variations in alignment of the extremities between serial examinations.

OWN MATERIAL

During the 10 year period from 1952 to 1961 orthoroentgenographic examinations were performed on 841 children at the Orthopaedic Hospital in Copenhagen. A modified Goldsten & Dreisinger technique was used. The patient is placed supine on the X-ray table. Hip, knee and ankle joints are marked on the skin. To secure correct marking a test exposure is made of the hip joints. Thereafter a 40 × 90 cm casette is placed under the legs. The feet are tied to a wedge-shaped support placed between the medial borders of the feet to secure a standard slight inward rotation. No further fixation is used.

6 separate exposures are made over the joints of the lower extremities with a tube to film distance of 100 cm. Proper focusing on the skin markers is secured by the aid of the light diafragm. No tubus is used.

Femoral and tibial length is measured between tangents—perpendicular to the border of the film—to the top of the femoral head, the lowest point on the medial femoral condyle, and the highest point in the groove lateral to the medial malleolus on the distal tibial joint surface in order to avoid inaccuracies from use of different rulers. The same ruler was used for measurement in all cases.

Among the examinations all those cases were selected, in which two or more measurements had been performed after completion of growth. Two cases were added, which had been measured twice with an interval *of 5 days and 7 days, respectively.*

In all cases with completed growth, epiphyseal closure was completed at the first of the two pictures. Films were stored and measured under equal conditions.

Two successive measurements of the same patient, in which bone length should theoretically be equal, were thus obtained in *29 patients*. In 2 of these cases the femoral length, and in one case the tibial length in the two measurements were not comparable due to surgical interventions between the measurements. This makes it possible to compare femoral length in 52 cases, tibial length in 56 cases, length of single

bones in 108 cases and length of the whole lower extremity in 50 cases Comparison of two measurements of the anisomelia can be performed in 25 cases and the difference between single bone pairs in 54 cases

RESULTS

The results of this investigation are given in Table 1

Cases where the second measurement exceeds the first are given as + variations and vice versa

The means ($\bar{x}$) do not deviate significantly from zero in any group

The standard deviations (s_x) are almost equal at femoral and tibial measurements (± 1 84 mm and ± 1 90 mm) while the standard deviation between measurements of the whole lower extremity is considerably greater (± 2 86 mm) than at isolated femoral and tibial measurement

The greatest deviations between measurements of whole lower extremities equal twice the standard deviation (± 5 72 mm) Mean length of the lower extremities in the material was 762 mm The maximum deviations thus amount to 5 72 × 100 762 = 0 75 per cent

The focusing can be read directly from the film The inaccuracy of focusing did not exceed 1 5 cm in any case From this a maximum error can be computed due to distortion of approximately 1 7 mm at each end of the femur and proximal end of the tibia and of approximately 1 0 mm at the distal end of the tibia

DISCUSSION

In some cases the errors were greater than the maximal distortion If inaccurate focusing was a major source of error one should expect greater inaccuracy in femoral than in tibial measurement as accurate focusing is most difficult and the object film distance is greatest at the hip joint If inaccurate focusing at the knee joint was of major importance for the error femoral and tibial inaccuracy would be oppositionally directed and therefore diminished when added to give whole lower extremity length

This investigation however showed no difference in accuracy between femoral and tibial measurements and a tendency to addition of deviations on femoral and tibial measurements in whole leg length measurements As other sources of error such as thermal and humidity expansion have been omitted these findings seem to indicate that

TABLE 1
Distribution of results

Differences between measurements	+6	+5	+4	+3	+2	+1	0	+1	+2	+3	+4	+5	+6	Total no. of obs.	Mean g mm	Standard deviation g mm
Nos. obs. femora		1	3	3	[illegible]	8	15	7	[illegible]	2	–	–	1	52	−0 [illegible]	±1 84
Nos. obs. tibiae	–		2	4	10	[illegible]	13	7	3	[illegible]	3	–	–	56	−0 05	±1 [illegible]0
Nos. obs. single bone	–	1	5	7	16	14	[illegible]8	11	1[illegible]	4	3	–	1	109	−0 17	±2 02
Nos. obs. whole lower extrem.	[illegible]	1	2	8	6	5	7	[illegible]	2	[illegible]	5	–	1	[illegible]0	−0 30	±2 86
Nos. obs. ant. semella			2	4	[illegible]	[illegible]	4	3	[illegible]	1	–	1	1	[illegible]5	−0 5[illegible]	±[illegible] 33
Nos. obs. diff. between single pairs of bones	1		[illegible]	4	9	1	9	7	[illegible]	1	1	2	1	51	−0 [illegible]	±2 [illegible]0

movements of the legs between single exposures and inaccuracy of positioning at separate examinations are the major sources of error.

The results of the investigation show that orthoroentgenographic measurement of the lower extremities is sufficiently exact for clinical use. The margin of error should, however, be kept in mind when scientific results are based upon such methods.

SUMMARY

Orthoroentgenographic double measurements of the lower extremities without intervening growth were collected from 29 patients. The standard deviations (s_x) between the two measurements were almost equal at femoral and tibia measurements (± 1.84 mm and ± 1.90 mm) and considerably greater between measurements of the whole lower extremity (± 2.86 mm).

Movements of the legs between single exposures and inaccuracy of positioning at separate examinations seemed to be the major sources of error.

Orthoroentgenographic measurement is sufficiently exact for clinical use but the errors may influence scientific results.

RÉSUMÉ

Une double mensuration orthoradiographique des extrémités inférieures sans qu'une croissance soit intervenue a été enregistrée chez 29 malades. Les déviations standard (s_x) entre les deux mensurations ont été pratiquement égales aux mensurations fémorales et tibiales (± 1.84 mm et ± 1.90 mm) et considérablement plus élevées entre les mensurations de toute l'extrémité inférieure (± 2.86 mm).

Les mouvements des jambes entre les différentes expositions et le manque de précision de la position aux examens séparés semblent être les principales sources d'erreurs.

Les mensurations orthoradiographiques sont suffisamment exactes pour usage clinique mais les erreurs peuvent exercer une influence sur les résultats *scientifiques*.

ZUSAMMENFASSUNG

Orthoröntgenographische Doppelmessungen der unteren Gliedmassen ohne intervenierendes Wachstum wurden von 29 Patienten gesammelt. Die Standardabweichungen (s_x) zwischen den beiden Messungen waren

fast die gleichen bei Femur und Tibiamessungen (± 1.84 mm und ± 1.90 mm) und bedeutend grösser zwischen Messungen der gesamten unteren Gliedmasse (± 2.86 mm).

Bewegungen der Beine zwischen den einzelnen Belichtungen und Ungenauigkeit der Lagerung bei den unterschiedlichen Belichtungen scheinen die hauptsächlichen Fehlerquellen darzustellen.

Orthoröntgenographische Messung ist hinreichend genau für die klinische Verwendung, aber die Fehlermöglichkeiten können wissenschaftliche Ergebnisse beeinflussen.

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STAPHYLOCOCCAL WOUND INFECTION COMPLICATING ORTHOPAEDIC OPERATIONS

By

LARS RÄF

INTRODUCTION

In the early nineteen fifties the hospitals became increasingly infected with antibiotic resistant staphylococci, especially the maternity and surgical wards. Epidemics of postoperative wound infections were reported where the infection rates exceeded 30 per cent. (By epidemic is generally meant that more than 6–8 per cent of operated patients become infected.) If comparable types of operations are investigated it is, however, questionable if the increase of infection rate during the last 15–20 years is real rather than merely apparent (1, 3, 5, 10).

Many studies concerning staphylococcal infections in general surgery have been published, including several from Scandinavia (3, 7, 8, 13). However, similar investigations in orthopaedic surgery are rare. Of 3 290 orthopaedic operations performed during 1959 at St. Mary's Hospital, Rochester, Minnesota, 1.7 per cent were postoperatively infected (4). I have only been able to find two other investigations, both from England (11), where 208 and 131 patients were operated upon and the postoperative infection rates were 2.9 per cent and 5.4 per cent respectively.

During the last decade the use of phage typing of staphylococci has increased. Aided by this and the antibiogram, i.e. the antibiotic-chemotherapeutic resistance pattern of bacteria, different groups of staphylococci can be distinguished, and the routes of infection can be more thoroughly mapped.

PRESENT INVESTIGATION

Material and Methods

Since 1959 in the Orthopaedic Department of St Göran's Hospital we have used Report of infection cards to register all operations on in-patients. On these cards are recorded, among other things, the personnel working in the operating theatre during the operation. The ward surgeon records on the card if the wound has healed per primam or if it has become infected. In the latter case he gives a short description of the infection. This is supplemented by information regarding the organism cultured, the course of infection and the final result of operation.

The Bacteriological Laboratory has since 1959 performed phage type and antibiogram on all cultures that have been positive for Staphylococcus aureus. All such cultures from the Orthopaedic Department have been registered on special lists together with the results of nose cultures regularly taken from the personnel working in the operating theatre and the wards. The laboratory records include all kinds of staphylococcal infections but by means of the clinical charts it has been possible to select all those infections which occurred postoperatively.

I have thus had access to two different systems of registration, the *report of infection cards* and the *records from the Bacteriological Laboratory*. Because of this double registration it is unlikely that any infection of importance has been overlooked.

Frequency of Wound Infection

In three years (from the third quarter of 1959 to the second quarter of 1962) there have been 1 925 operations on in-patients in the Orthopaedic Department. A few cases that were preoperatively infected are included in this figure. Closed reductions and various kinds of percutaneous operations are excluded. In 75 cases (3.9 per cent) wound infection due to staphylococcus aureus occurred postoperatively. There have only been a few cases of wound infection due to other bacteria and no cases caused by β haemolytic streptococci. The infection rate for men was 3.6 per cent and for woman 4.2 per cent, thus there is no significant difference. The infection rate increases markedly with age (Fig. 1).

Fig. 2 illustrates the quarterly infection rates during the three years of this investigation. The infection rate has been higher during the fourth to the eighth quarter than during other parts of the observation time. A similar increase will appear even if only those cases are in-

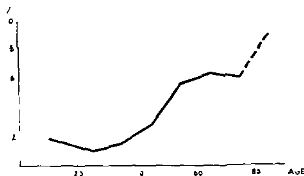


Fig 1
Frequency of staphylococcal wound infections in different age groups
(1 9?5 operations)

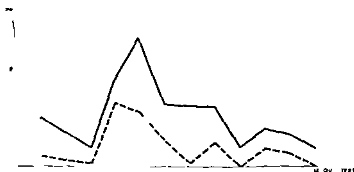


Fig 2
Frequ nc f wound infecti n quartely during a three ears observation period
(1 9?5 operati n)

cluded where the final result has been affected by infection This contradicts the supposition that the increase is due to increased care and attention and to an increased frequency of bacterial cultures during that time In the fourth and the fifth quarters the infection rate has exceeded 6 per cent so by the definition given above one can speak of an epidemic of wound infection during this time

Frequency of wound infection in different body regions

Table 1 shows the distribution in different regions Operations in hip spine and thigh knee have had the highest infection rate

TABLE 1

Frequency of wound infection in different body regions

Region	Number of operations	Number of infections	Frequency of infection
Hip	528	31	5.9
Spine	288	15	5.2
Thigh knee	241	11	4.5
Calf	183	5	2.7
Foot	481	13	2.7
Arm	124	0	0
Other	80	0	0
Total	1925	75	3.9

Time of Onset of Infection

In 47 cases (63 per cent) deep infection appeared soon after the operation. In these cases contamination probably occurred at the time of operation. In the remaining 28 cases (37 per cent) the infection did not appear until after the first change of the dressing. In these cases contamination in the wards cannot be excluded.

Results of Wound Infection

In Table 2 I have tried to show the consequences of the infections. In 37 per cent the infection has compromised the result of the operation.

TABLE 2

Consequences of wound infection

	Number of cases	%
Postoperative course not affected by infection	25	33
Postoperative course but not final result affected by infection	22	30
Final result affected by infection	28	37

Staphylococcal Strains

With reference to phage patterns and antibiograms the isolated staphylococcal strains have been divided into different groups *and* subgroups (Table 3).

TABLE 3

Presence of staphylococci with certain definite phage patterns and antibiograms in connection with wound infections following orthopaedic operations

Phage group	Sub group	Phage pattern	Antibiogram S	P	Str	Te†	Number of inf
I	I a	*52 52A/80/KS6*	3	3	3	3	5
	I b	*52 52A/80 81/KS6*	0	1	0	3	4
II		3A 3B/3C/55/71	3	3	3	3	3
III	III a	*6/7/42E/47/53/75/77*	3	1 2	3	3	26
	III b	*6/7/47/53 54/75/77*	1	1	0	1	5
Other		Varying (fewer than 3 cases of infection per phage pattern/antibiogram type) and non typable					32

Italic figures and letters indicate those phages most regularly causing lysis

† S Sulphonamides P Penicillin Str Streptomycin Te Tetracyclines

Many staphylococcal strains especially in group III but also in other groups react with such common and uncharacteristic phage patterns that a more detailed typing of them is not possible Such strains with similar patterns can sometimes be differentiated by the antibiogram e g those strains in Table 3 indicated by sub groups I a and I b and III a and III b The figures in the antibiogram mark the degree of sensitivity of the bacteria to the antibiotic -chemotherapeutics mentioned 3 indicating full sensitivity and 0 full resistance

In this material one staphylococcal strain in group III named sub group III a has been the most common cause of infection among these staphylococci that have been possible to phage type The frequency of wound infections by this strain shows a heavy increase during the fourth and fifth quarter (Fig 3)

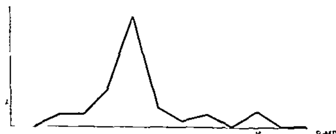


Fig 3

Quarterly frequency of wound infections caused by staphylococci belonging to sub group III a

Carriers of Staphylococci

The nasal carrier rates for the operating room personnel are shown in Table 4.—16 of 36 persons have been practically permanent nasal carriers.

TABLE 4

Nasal carriers of staphylococci among the operating room personnel
36 persons examined four or more times in a period of four months or longer
(Average 13 specimens per person)

Nose cultures	Number of persons
Positive in half or more of the specimens	16
Positive in less than half of the specimens	15
Negative in all specimens	5

Association of Surgeon to Wound Infection

The incidence of wound infection for different surgeons has varied widely (Table 5).

TABLE 5

Incidence of infection for different surgeons (Only those who have performed more than 100 operations are included.)

Surgeon	Incidence of infection	Incidence of primary infections (%)
A	8.3	8.3
B	4.5	[illegible]
C	4.1	1.9
D	3.8	0
E	3.[illegible]	2
F	3.4	2.0
G	2.7	0

Surgeon A has had a much higher infection rate than the others. This difference becomes even more pronounced if only those infections are included where the contamination seems to have occurred during the operation (see above). In Table 5 these infections are called primary infections.

The results of the nose cultures from the personnel show that all surgeon A's nose cultures and repeated nose cultures on surgeon E showed staphylococcus III a. A worked in the department during the

above mentioned epidemic and he took part in 9 of the 10 operations which during the fifth quarter became infected by this organism. F did not work in the department during the epidemic but two patients he operated upon during the second quarter became infected by the same strain. Intermittently surgeon G has had in his nose a strain belonging to group II. One patient operated by him became infected by staphylococci belonging to this group. I have been unable to find any other associations between staphylococci from personnel and from wounds.

DISCUSSION

I have tried to illustrate the clinical features and epidemiology of the postoperative staphylococcal infection in an orthopaedic department.

The frequency of infection has varied considerably during the three years of this investigation. Previous investigations (4, 6, 9) have shown that contamination of the wound has generally occurred during the operation. This also seems to have been the case in our material as $^2/_3$ of the infections appeared in close connection with the operation.

Several authors have shown that the source of wound contamination often can be traced to nasal carriers among the operating theatre personnel (2, 4, 6, 9, 12). The outbreak of infections during the fourth and the fifth quarters can be assigned with great probability to a certain surgeon being a permanent nasal carrier of a strain belonging to group III. Unfortunately no culture was made from his skin, but as he had a hand eczema during this period it is not improbable that he was also a so-called skin carrier. Such persons increase the risk of infection in the operative field because of the well known high percentage of glove puncture (2, 11).

Among the operation personnel 44 per cent have been almost permanent and a further 42 per cent intermittent nasal carriers of staphylococci. Under such circumstances it is not feasible to exclude all carriers of staphylococci from work in the operating rooms. Carriers of strains frequently causing wound infection should, however, be carefully observed and should not take part in the operative work if they manifest the slightest sign of skin or respiratory infection.

I have not been able to show any clear routes of infection in the wards, but the reason for this may be paucity of data. Nor have I been able to investigate the significance of nasal carriers among the patients because cultures were not done on them. It has been stated that there

is a higher frequency of postoperative infections among staphylococcal carriers than among other patients (11).

I have found that the wound infections have been registered carefully on the report of infection cards, but the system has proved unnecessarily laborious and the cards difficult to survey. I therefore recommend the following simplifications:

1. The report of infection cards should be abandoned, and instead the names of the personnel present at the operation should be noted in the patients' chart or anaesthetic record.

2. Bacterial cultures should continue to be taken from all wounds that are suspected of infection. A copy of all positive bacterial cultures from in-patients should be sent to the Infection Committee, i.e. a surgeon and a bacteriologist.

3. All postoperative infections should be recorded in an infection register including such facts as may subsequently lead to the establishment of routes of infection.

The number of post-operative wound infections in our department has been about two per month, and bearing in mind the serious consequences that they bring, the increased work in registering infections is certainly worth while if it leads to the sources of infection and effective counter-measures.

SUMMARY

Almost 2 000 orthopaedic operations covering a three-year period were studied for postoperative wound infection. The incidence of postoperative staphylococcal wound infection was 3.9 per cent. The incidence increased greatly with age but there was no significant difference in sex incidence. Operations on the hip, spine and thigh-knee showed the highest frequency of infection. In two-thirds of the cases the course of infection indicates that the bacterial contamination occurred during the operation. The final result of operation was impaired by the wound infection in more than one third of the cases. During the three years in question there was an epidemic of infections caused by staphylococci of phage type 6/47/53/75 belonging to group III. In most of these cases the contamination seems to have been transferred from a surgeon who was a chronic carrier of this strain. Finally, a suitable method of registering postoperative wound infection is discussed in order to facilitate the detection of an increased frequency and appropriate counter-action.

RÉSUMÉ

2 000 opérations orthopédiques environ s'étendant sur une période de trois ans ont été étudiées par rapport aux infections post-opératoires de la plaie. On a constaté une fréquence d'infections staphylococciques post-opératoires de la plaie de 3,9 pour cent. La fréquence augmente beaucoup avec l'âge, mais il n'y a aucune différence entre les sexes. Les opérations de la hanche, de la colonne vertébrale et de la cuisse-genou accusent la fréquence la plus élevée d'infection. Dans deux tiers des cas l'évolution de l'infection montre que la contamination bactérienne a eu lieu pendant l'opération. Le résultat final de l'intervention a été diminué par l'infection de la plaie dans plus d'un tiers de ces cas. *Durant les trois années en question il y a eu une épi*démie d'infections causées par staphylococcie du type 6/47/53/75 appartenant au groupe III. Dans la plupart des cas la contagion semble avoir été transmise par un chirurgien porteur chronique de ce type. Il est discuté pour terminer d'une méthode permettant d'enregistrer les infections postopératoires de la plaie afin de faciliter la découverte d'une fréquence accrue et de pouvoir prendre des mesures appropriées.

ZUSAMMENFASSUNG

Etwa 2000 orthopädische Operationen, die während einer dreijährigen Periode ausgeführt worden waren, wurden hinsichtlich postoperativer Wundinfektion untersucht. In 3,9 Prozent trat eine postoperative Wundinfektion mit Staphylokokken auf. Das Auftreten nahm sehr mit dem Alter zu, aber kein Unterschied hinsichtlich der Geschlechtsverteilung konnte beobachtet werden. Operationen an der Hüfte, Wirbelsäule und Oberschenkel-Knie zeigten die häufigsten Infektionen. In zwei Drittel der Fälle wieste der Verlauf der Infektion darauf hin, dass die bakterielle Verunreinigung während der Operation geschah. Das Endergebnis der Operation wurde durch die Wundinfektion in mehr als einem Drittels der Fälle herabgesetzt. Während der hier in Frage kommenden drei Jahre entstand eine epidemische Infektion, die durch Staphylokokken der Phagustype 6/47/53/75 zur Gruppe III gehörig hervorgerufen worden war. In den meisten dieser Fälle scheint die Infektion von einem Chirurgen, der ein chronischer Träger dieser Abart war, übertragen worden zu sein. Am Schlusse wird eine brauchbare Methode zur Registrierung von postoperativer Wundinfektion besprochen, die es möglich machen soll, die Entdeckung einer erhöhten

Häufigkeit und die Durchführung entsprechender Gegenmassnahmen zu erleichtern

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INFLUENCE OF FRONTAL AND DORSAL LOADS ON MUSCLE ACTIVITY AND ON THE WEIGHT DISTRIBUTION IN THE FEET

By

SVEN CARLSÖÖ

If a person who has adopted an upright symmetric standing rest position has his back loaded by, for instance, a heavy rucksack on the shoulders or a box which he holds in front of him, he alters his posture spontaneously in order to compensate for this load. Through changes in the position of various joints the line representing the combined gravitational pull of the body and the load will thus pass through the area on which the person is standing.

Such a load and the changes in posture result in an increased load on the musculature and a modified distribution of muscle activity as compared with the original posture.

The object of this investigation has been to make comparisons between the muscle activity in the major postural muscles when standing with and without a load and also when walking with and without a load. Investigations were likewise made into the distribution of the body's weight between the right and left foot and between forefoot and heel in a standing position, with and without a load.

METHOD

Fifteen students between the ages of 19 and 21 were examined. Muscle activity was recorded with a Disa electromyograph, using surface electrodes. The muscles studied were sacro-spinalis, rectus abdominis, tibialis anterior, quadriceps, the ischiocrural muscles, soleus and trapezius.

The pressure exerted by the weight of the body on its support was measured by means of two stress plates, one under the left heel and

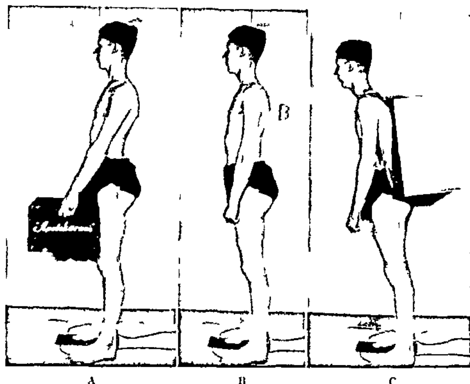


Fig. 1.
Subject standing—without a load, with a front load and with a back load—with the left foot on the two stress plates used for measuring heel and forefoot pressure and with a simple metal plate under the right foot.

one under the left forefoot (Fig. 1). The right foot stood on a simple *metal plate of the same thickness as the stress plates. The stress plate* used for measuring heel pressure has been described previously (*Wetenstein* 1961). The stress plate for the forefoot was designed on the same principles as that for the heel, i.e. a stiff spring balance consisting of a plate which is carried by three cantilevers on which are mounted strain gauges—but was somewhat larger so as to support the entire forefoot. There was no support for the arch of the foot. *The load on the left foot is thus the sum of the pressures of these two plates.* The load on the right foot is then the difference between this sum and the total body weight.

During the investigations the subjects were dressed in light trousers or gymn clothes. For the registration of the foot loads they were required to adopt a symmetric rest posture with what they considered to be an even distribution of weigth between sole and forefoot. Once in

this posture recordings were made during a period of five seconds using a Visicorder mirror galvanometer.

The subjects then remained on the plates while the load was attached to the shoulders by means of leather straps. The total weight of this load, hereinafter referred to as the "back load", was 20.5 kg (Fig. 1 c).

As soon as the subject had adopted a comfortable and balanced posture another five second registration of the foot loads was made. Subsequently the back load was exchanged for a front load, this time a 20.5 kg box which the subject held in his hands in front of him (Fig. 1 a). Once a balanced posture had been achieved the third registration was made. Even within a five second period the postural sway produces fluctuations on the pressure curves, but the measurements from these curves were taken from the periods of minimum fluctuation.

The muscle activity was first registered with the subject in an upright symmetric standing rest position and then during walking. Next the activity was registered in the standing position with the back load and then walking with the same load. Corresponding registrations were then made standing and walking with the front load. In the standing positions the registrations were made after the subject had adopted the most comfortable and balanced position possible. The registrations were then made during a thirty second period. During the walking tests the subject walked in a straight line for about five meters at a smooth, even pace.

RESULTS AND DISCUSSION

Foot loads (Tables 1, 2 and 3, Figs. 2 and 3)

When standing symmetrically in a rest posture ten of the fifteen subjects put more weight on the right foot than on the left, while the remaining five put more on the left than on the right. In thirteen of the fifteen cases there was more weight on the left forefoot than on the left heel. *Abramson* (1927), on the other hand, found that an average of 57 per cent of the weight was on the heel and 43 per cent on the forefoot and arch. This discrepancy is probably attributable to different methods of measuring and possibly even more to different procedures. *Abramson* used the Brinell method and measured the foot's pressure at a number of points on the support. The subjects stood upright but with the body weight all on one foot while the other foot was immediately above the measuring instrument. The latter foot was then lowered on to the measuring plate so that the body weight was dis-

TABLE 1

Symmetric Rest Position

Subjects	Sex	Height	Weight	On left heel plate		On left forefoot plate	
				Vertical pressure in kg	of body weight	Vertical pressure in kg	of body weight
I B	♀	168	58 6	12	21	17	37
B T	♀	163	59 6	11	18 5	18	30 03
B R	♀	164	62 5	13	21 6	16 5	26 8
K F	♀	170	65 7	18	27 4	16	24 35
I O	♂	171	65 8	7	10 6	23	35
C B	♂	172	66 5	12	18 05	21	31 6
J P	♂	186	66 6	12	18	24	36
T F	♂	180	72 2	10 5	14 6	21 5	29 8
U B	♂	180	73 2	18	24 6	20	27 3
B H	♂	172	74 3	16	21 5	19	25 6
B F	♂	175	75 2	12	15 95	26	34 55
B A	♂	183	77	17	22	22	28 5
K B	♂	179	77 5	7	9 4	24	30 9
D B	♂	181	80 1	21	26 2	19	23 7
H A	♂	183	83	12	14 45	20	24 2

TABLE 2

Standing with Back Load

Subject	Sex	Height	Weight	On left heel plate		On left forefoot plate	
				Vertical pressure in kg	of body weight and load	Vertical pressure in kg	of body weight and load
I B	♀	168	58 6	16	20 2	28	35 2
B T	♀	163	59 6	6	7 5	35	43 7
B R	♀	164	62 5	16	19 3	21	25 3
K I	♀	170	65 7	14	16 23	30	34 8
I O	♂	171	65 8	8	9 28	30	34 8
C B	♂	172	66 5	5	5 76	42	48 2
J P	♂	186	66 6	18 5	20 07	28	32 15
T F	♂	180	72 2	14	15 1	26	28
U B	♂	180	73 2	12	12 8	33	35 2
B H	♂	172	74 3	10	9 48	32	33 8
B F	♂	175	75 2	15	15 78	31	32 35
B A	♂	183	77	17 5	17 95	27	27 7
K B	♂	179	77 5	10	9 8	28	28 6
D B	♂	181	80 1	23	23 9	24	23 9
H A	♂	183	83	9	8 7	37	36

tributed between the two feet Two seconds later the foot was raised again from the measuring plate It is questionable whether during such a brief period it is possible to distribute the body weight between the two feet in a manner which is entirely consistent with a symmetric upright resting posture

TABLE 3
Standing with Front Load

Subjects	Sex	Height	Weight	On left heel plate: Vertical pressure in kg	On left heel plate: % of body weight and load	On left forefoot plate: Vertical pressure in kg	On left forefoot plate: % of body weight and load
I B	♀	168	58.6	9	11.35	31	39.2
B T	♀	163	59.6	8	10	33	41.2
B R	♀	164	62.5	8	9.64	30	36.3
K.F	♀	170	65.7	14	16.26	29	33.6
L.O	♂	171	65.8	13.5	15.7	26.5	30.7
C B	♂	172	66.5	23	29.1	26.5	30.5
J I	♂	186	66.6	11.5	13	29	33.3
T E.	♂	180	72.2	16	17.2	26	28
I B	♂	180	73.2	21	22.4	25.5	27.5
B.H	♂	172	74.3	18	19	25	26.4
B F	♂	175	75.2	22	23	[illegible]5.5	26
B A	♂	183	77	16	16.4	[illegible]7	24.6
K.B	♂	179	77.5	11	11.2	35	33.9
D B	♂	181	80.1	24	23.8	27	26.[illegible]
H A	♂	183	83	18	17.35	25	24.2

If the subject stood with the 20 5 kg box held in front of him or if the box were strapped on his back this addition to the body weight tended to load the forefoot more than the heel This proved to be so in twelve of the fifteen cases with the back load and in nine of the fifteen cases with the front load There were large individual variations The relationship heel load:forefoot load varied in one case between 0 28 and 0 32 while in another case the variation was from 1 13 to 0 58 Ventral shifting of the point where the line of gravity passes through the area supporting the body may be seen as a safety measure A person who loses his balance is more likely to fall forwards than backwards His field of vision and the range of movement of the arms give him a much better chance of saving himself if he falls forwards

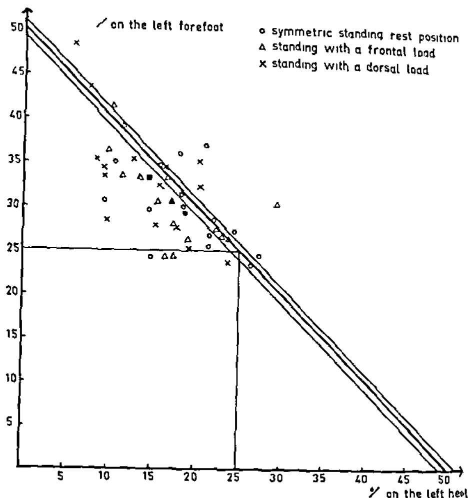


Fig. 2

The percentage of the bodyweight carried by the left heel and left forefoot respectively with the subject standing symmetrically with and without a load

MUSCLE ACTIVITY

With the subject standing in a symmetric rest position it was possible regularly to register activity in sacro spinalis and soleus. Often though not regularly it was also possible to register activity in the ischiocrural musculature. On the other hand it was never possible to register activity in tibialis anterior, quadriceps or rectus abdominis. These results confirm earlier investigations (*Åkerblom* 1948, *Floyd & Silver* 1950, 1955, *Joseph, Nightingale & Williams* 1955, *Joseph & Williams* 1957, *Portnoy & Morin* 1958, *Carlsöö* 1961). Slight activity was registered in trapezius

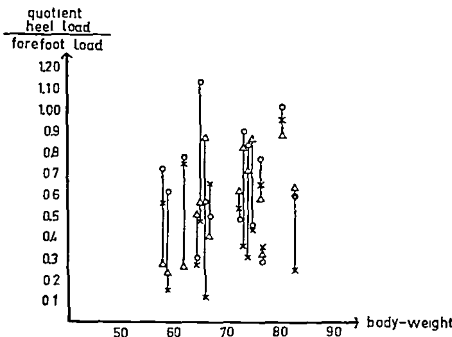


Fig 3

The diagram shows the changes in the ratio between the loads on the left heel and left forefoot when subject standing symmetrically without a load ( ) receive a back load (o) or a front load (x)

Activity in trapezius, soleus and rectus abdominis was always more pronounced *with the back load* than without a load, whereas tibialis anterior and quadriceps were always passive.

With the back loaded the ischiocrural muscles showed large variations. In certain cases the activity increased, in others it diminished, while in some cases the activity was much the same as in the standing rest position. Sacro-spinalis, on the other hand, displayed much less activity and in certain cases none at all.

No further report will be made here on the activity during walking of the muscles investigated, since this will be dealt with in a later paper and in another connection. However, it should be noted at this point that the activity in sacro-spinalis is considerably less when walking with a back load than without, in other words the conditions are analogous with the standing position (Fig. 4).

When standing *with the front load* the activity in soleus and trapezius

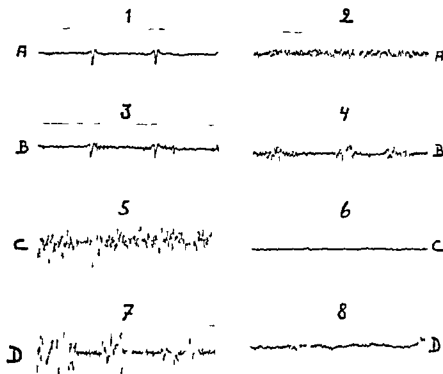


Fig 4

A standing in rest position B walking without load C standing with back load. D walking with back load Records 1 3 5 and 7 from m rectus abdominis and records 2 4 6 and 8 from m sacro spinalis

was much the same as with the back load There was regular pronounced activity in sacro spinalis

As with the back load the ischiocrural muscles displayed individual variations In some subjects they were pronouncedly active while in others they were passive Rectus abdominis tibialis anterior and quadriceps remained completely inactive

When the subjects altered their posture to counterbalance the back load *this change took the form mainly of increased thoracic kyphosis* flexion of the trunk at the hip joint (ca 15) and flexion of the talo crural joint (ca 5) If this position is adopted voluntarily without a back load then the activity in sacro spinalis is always more pronounced than when standing in the upright rest position without a load A back load would thus seem to relieve sacro spinalis The explanation for this must be that the back load helps counterbalance the trunk s tendency

to fall forward a function which falls chiefly to erector spinae in the upright symmetric rest position If the subject was requested to lean even further forward as he stood with the back load the activity in sacro-spinalis increased and became about the same as in the symmetric upright rest position In other words leaning forwards is a way of compensating for the backwards pull of a back load This forward leaning however is not so pronounced that the muscle is loaded to the same extent as it is in the upright symmetric rest position On the other hand there was pronounced activity in rectus abdominis with the back load At the same time as a back load relieves the deep muscles of the back it loads the abdominal muscles

If the body leans forward without a back load from the symmetric standing rest position the flexion in the hip joints is generally accompanied by extension in the talocrural joints and a slight flexion in the knee joints With the back load in question on the other hand all the subjects stood with the crus bent forward somewhat which partly explains the pronounced activity in soleus It would seem that the individual variations in the activity of the ischiocrural musculature are connected with the degree of flexion at the hips Further investigations revealed that if the subjects leant further forwards than normal activity in the ischiocrural muscles always increased If on the other hand they leant less than normal activity in these muscles diminished or ceased altogether It seems that when activity is present the trunk s centre of gravity is in front of the transverse axis of the hip joints and that when there is no activity the line of gravity passes through or behind this axis The ischiocrural muscles could also be relieved in the standing position with a back load by slightly bending the knees

The distribution of weight between the different muscles within the ischiocrural group depends upon the position of the feet The wider the angle at which the feet are set the greater the load on biceps femoris the smaller the angle the greater the load on the medial muscles

With the front load the effect on the body is compensated partly by increased lumbar lordosis and partly through a slight extension in the hip joints backward tilting of the head and a backward inclination of the crus

Since the front load accentuates the normal tendency of the trunk to fall forward when in an upright standing position it follows that a weight in the hands increases the load on sacro spinalis at the same time as it relieves rectur abdominis The fact that the load on the

ischiocrural muscles varied so much may be explained by the same reasons as are discussed above.

When in an upright symmetric rest position the body makes a slight backward extension in the talocrural joint, the activity in soleus diminishes because the line of gravity of the body approaches the transverse axis of this joint. Such a movement with a front load does not involve dorsal displacement of the centre of gravity. As mentioned earlier, the centre of gravity is instead displaced towards the forefoot. The moment arm of the load is increased and this, combined with the increased load, explains the pronounced activity in soleus. The pronounced activity in trapezius is naturally connected with the load on the shoulders, whether directly through the straps or indirectly via the arms.

SUMMARY

Muscle activity in the major postural muscles was studied electromyographically on fifteen students carrying different loads. The tests were made in the standing position and while walking. Investigations were also made into how the body weight is distributed between the heel and forefoot in a symmetric standing position, with a front load held in the arms and with a back load attached to the shoulders.

RÉSUMÉ

L'activité des muscles dans les principaux muscles de posture a été étudiée par électromyographie chez quinze étudiants portant différents poids. Les essais on été pratiqués en position debout et pendant la marche. On a cherché par ailleurs a étudier comment se repartit le poids du corps entre le talon et l'avant pied en position debout symétrique avec un poids frontal tenu dans les bras et avec un poids arrière attache aux epaules.

ZUSAMMENFASSUNG

Die Muskeltätigkeit in den grösseren Haltungsmuskeln von fünfzehn Studenten, die verschiedene Lasten trugen, wurde mittels Elektromyographie untersucht. Die Proben wurden im Stehen und während des Gehens vorgenommen. Die Verteilung des Körpergewichtes zwischen der Ferse und dem Vorfuss bei einer symetrischen stehenden Stellung mit einer voran in den Armen gehaltenen Last und mit einer rückwärts an den Schultern befestigten Last wurde ebenfalls untersucht.

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SAGITTAL MOBILITY OF THE HIP JOINT

By

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The sagittal range of mobility of the hip is defined for the purpose of this study as the angular difference in maximum extension and flexion This range of mobility will be referred to below as *total flexion* Whereas it is usual to specify the flexion and extension of the joint separately in this study it is assumed that the total flexion is the sum of these two components *Milch* (5) points out that the common methods of measuring the flexion of the hip joint do not take account of the simultaneous mobility of the pelvis and that the values so obtained may therefore be misleading He suggests that instead of using the table or horizontal plane as the reference line a more accurate measure is provided by the difference in the angle formed by the axis of the shaft of the femur and Nelaton s line (the pelvi femoral angle) in maximum flexion and extension *Milch* found this angle to be 50 in the normal subject with the hip joint fully extended in maximum flexion this angle will be about 125 giving a total flexion of about 75

Milch s values contrast with those given in the usual textbooks which range from 130–140

	Flexion	Extension	Total flexion
Milch (5)			75
Fick (2)	121	13	134
Lantz & Wachsmuth (4)	120	15	135
Chapchal (1)	110 (120)	20	130 (140)
Ama (7)	100	30	130
Howorth (3)	120	20	140

These authors measured flexion in the supine position and extension in the prone position In Thomas method for measuring the flexion contracture it was prescribed that lumbar lordosis should be obliterated

1 Radiologist Orthopaedic surgeon Passive movements

It is not indicated whether this should apply also in the measurement of flexion and extension and details of the technique are often lacking

To explore the reasons for the discrepancies between the reported values for the range of mobility of the hip-joint and to study the movement of the pelvis in an examination of this joint a series of examinations of the mobility of the hip-joint were performed this was determined by various clinical methods and by radiography From these studies a new clinical method for determining the total flexion of the hip was developed

MATERIAL AND METHODS

The study was performed using 95 subjects with normal hips and on 10 cases of osteoarthritis

Thomas Method

Flexion The patient was placed in the supine position The angle formed by the longitudinal axis of the thigh and the table was determined after flexion of the thigh up to the abdomen or if it would not close up to the abdomen until the lumbar lordosis was apparently eliminated During this movement the other leg was kept in contact with the table or permitted to follow into a flexion position (Fig 1 A)

Extension Patient in the prone position The angle between the longitudinal axis of the thigh and the table was determined by lifting the leg until a moderate resistance was encountered and with the pelvis maintaining contact with the table (Fig 1 B) The other leg remained on the table

Flexion contracture The hip not under examination was flexed up to the abdomen or if resistance was encountered earlier until the lumbar lordosis was apparently eliminated The angle between the axis of the thigh under examination and the table was determined (Fig 1 C)

When there was a flexion contracture this was subtracted from the flexion mobility to give the flexion of the hip-joint in these cases no examination of extension was made

Milch s Method

The patient was examined in the lateral position with the examined leg uppermost The hip was extended fully with an increase in the lumbar lordosis and in this position the axis of the femur was drawn on the skin as was Nélaton s line (spina iliaca anterior superior—tuber

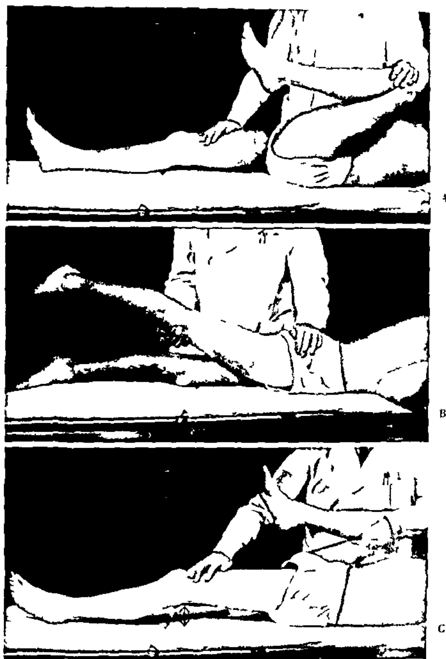


Fig 1

Determination of flexion of the hip joint by Thomas method
A flexion B extension C flexion contracture

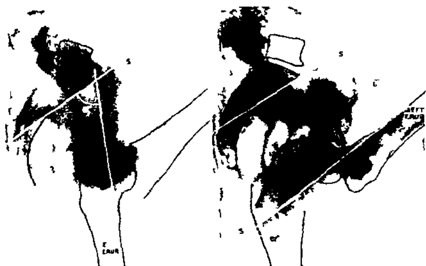


Fig 2
Radiographic measurement of total flexion of the left hip joint

ischii) The angle between these lines was measured The same leg was then flexed fully while the other leg was kept straight The two lines were again drawn on the skin and the angle so formed measured

Radiographic Measurement

Lateral projections were used to obtain the angles between the axis of the femur and various reference lines on the pelvis (Fig 2) The film focus distance was about 100 cm The examined leg was nearer the film and the beam was centered on the head of the femur The upper part of the anterior surface of the sacrum (S) was used as the reference line on the pelvis Where there was no rotation of the pelvis in any other plane the angles measured on the films were taken as the true angles account being taken of a measurement error of about 3 which was ascertained by repeating the measurements

RESULTS

Comparison between Clinical Measurements Obtained by Two Investigators

Two physiotherapists independently examined 24 hips by the methods of Milch and Thomas The angles were measured to the nearest 5

TABLE 1

Normal subjects	Flexion (Thomas) I	Flexion (Thomas) II	Total flexion (Milch) I	Total flexion (Milch) II	Pelvo-femoral angle in tension I	Pelvo-femoral angle in tension II
1	145	140	75	75	50	50
2	130	140	70	70	50	50
3	140	135	75	75	50	50
4	130	140	70	75	50	45
5	135	130	65	70	45	50
6	130	135	70	65	50	50
7	125	130	70	75	50	50
8	140	150	65	65	50	50
9	150	145	70	70	50	50
10	145	140	70	75	50	50
11	140	150	75	85	50	50
12	150	150	75	70	50	50
13	135	145	75	75	50	50
14	140	145	75	75	50	50
15	125	120	60	40	60	60
16	130	140	85	70	45	50
17	110	100	60	45	50	60
18	140	145	65	65	50	50
19	120	130	60	70	50	50
20	130	150	70	75	50	50
Cases of osteoarthritis						
21	65	60	30	25	60	60
22	80	70	50	50	60	60
23	30	30	20	25	70	80
24	95	70	60	45	55	60

Investigator I Investigator II

There was a close agreement between the results obtained by the two investigators as seen from the following summary of Table 1

Difference in measurements	0	5	10	15	20	25
Number of comparisons	28	25	14	3	2	0

Thus a difference of 5° or less was obtained in 74 per cent of the measurements

There was a considerable difference in the flexion values yielded by the two methods

Difference in flexion between Thomas & Milch's methods	≤50	55	60	65	70	75	80	85
Number of comparisons	10	3	9	8	7	6	4	1

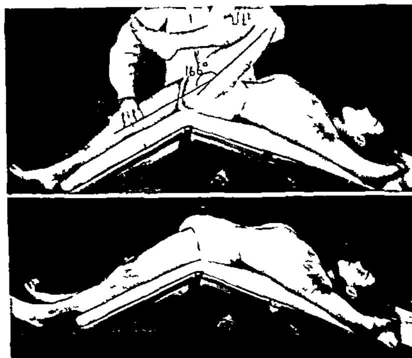


Fig. 34

Determination of total flexion of the hip-joint by the author's method on a table with a dropped end

On an average Milch's method for total flexion gave values that were 60° smaller than did Thomas' method for flexion alone. No extension mobility was included in the Thomas values; the difference would then have been even greater.

Radiographic Examination of Hip-Joint and Pelvis Mobility for Different Positions of the Leg and Trunk

An analysis of the mobility of the pelvis and hip-joint in different positions of the body performed on 10 subjects gave the following results. The relation between the pelvis and femur differed in the supine and prone positions. The difference in angle ranged from 3° to 15°, the hip-joint usually being flexed more in the prone position. In the supine posture with the leg straight there was a flexion of the hip joint of 7–22°. In flexion to 90° the movement was restricted almost entirely to the hip-joint, but beyond this the pelvis was also involved. In ex-

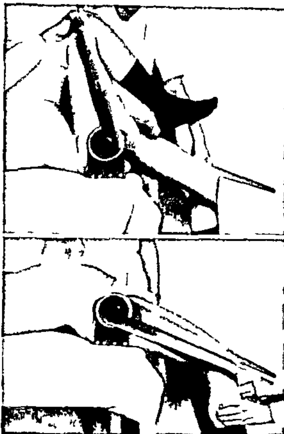


Fig 3 B
Determination of total flexion of the hip joint by the author s method on an ordinary examination couch using a special device for measuring the angle

tension the movement took place simultaneously in the pelvis and hip-joint In the erect position there was a flexion of 0 –25°

Full extension of the hip-joint could be obtained in two ways

(i) The leg not being examined could be flexed up to the abdomen (when the pelvis was also flexed) with the other leg still in contact with the table fully extended or (ii) in the supine position both legs could be extended 30–60 to the horizontal plane The latter procedure was necessary where the abdomen was large or the range of mobility was great

Full flexion was obtained when the examined leg was bent fully and the other leg was kept on the table If this leg was also flexed up to the abdomen the pelvis was rotated so that full flexion was lost In the case of exceptionally great mobility of the hip-joint—and large abdomen—full flexion of the examined leg could sometimes be obtained only on rotating the pelvis by dropping the other leg below the horizontal plane

A New Method for Determining Total Flexion of the Hip Joint

On the basis of the data obtained from this radiographic analysis a new clinical mensuration technique was developed. The subject is placed in the supine position (i) on a table one end of which could be dropped so as to obtain full extension of the hip-joint (Fig. 3 A) or (ii) on an ordinary examination couch but with both legs hanging over the short end (Fig. 3 B). Both legs are then extended fully by dropping them through an angle of 30–60, whereby the lumbar spine is strongly lordosed. The leg not being examined and hence the pelvis are locked in this extended position. The examined leg is then flexed until an elastic resistance is encountered; with this method this will occur some distance from the abdomen. The angular movement of the leg is measured. If the extension differs on the two sides the procedure is in principle the same. If the joint with the smaller range of mobility is examined it should be ensured that the pelvis is locked in extension by extending the leg not being examined more than the other one.

To facilitate the determination of the range of mobility of the hip a special device for measuring the angle has been designed.[1] When the hip-joint is fully extended, one arm of the angle measuring device together with the scale can then be locked parallel to the thigh. The other arm can be set parallel to the thigh which is flexed. The total flexion of the joint can then be read off on the scale (Fig. 3 B).

Comparison between the Methods

From Table 2, which shows the values for 22 hip-joints examined, it is seen that there is a close agreement between the new clinical method and the radiographic measurement.

Thomas' method gave too high values. When only the flexion angles obtained by this method were used the values were slightly on the high side. The method of Milch gave very low values.

Examination of Normal Subjects by the New Method

Measurements were performed on 7–10 men in each decade between 20 and 80 years and without hip symptoms. The total flexion of the hip-joint showed a large individual variation with values ranging from 107 to 170; on an average this mobility decreased with age (Table 3).

[1] AB Stille-Werner, Stockholm.

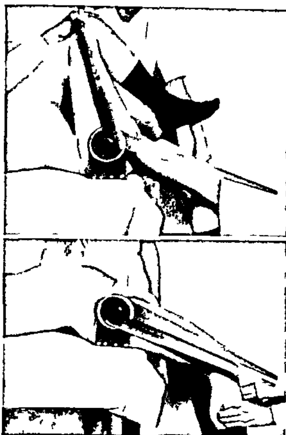


Fig 3 B

Determination of total flexion of the hip joint by the author's method on an ordinary examination couch using a special device for measuring the angle

tension the movement took place simultaneously in the pelvis and hip-joint In the erect position there was a flexion of 9–25

Full extension of the hip joint could be obtained in two ways

(i) The leg not being examined could be flexed up to the abdomen (when the pelvis was also flexed) with the other leg still in contact with the table fully extended or (ii) in the supine position both legs could be extended 30–60 to the horizontal plane The latter procedure was necessary where the abdomen was large or the range of mobility was great

Full flexion was obtained when the examined leg was bent fully and the other leg was kept on the table If this leg was also flexed up to the abdomen the pelvis was rotated so that full flexion was lost In the case of exceptionally great mobility of the hip-joint—and large abdomen—full flexion of the examined leg could sometimes be obtained only on rotating the pelvis by dropping the other leg below the horizontal plane

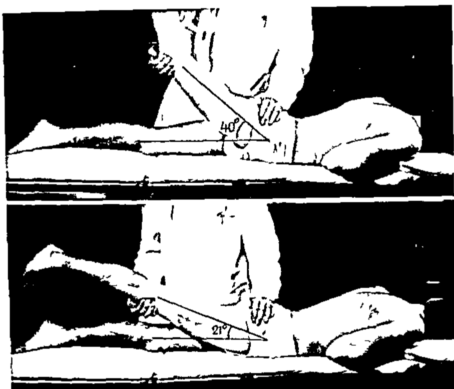


Fig 4
Determination of extension by Thomas method
The final position is difficult to determine

likewise unsuitable since it gives too high values The reason for this is that the mobility of the pelvis is included in both flexion and extension and that the reference position from which the measurements are made changes as the patient is turned

A further source of discrepancy in this method is the uncertainty whether the flexion should be continued until the lumbar lordosis is normal or straight or perhaps even changed to kyphosis

The flexion values given by Thomas method are in close agreement with those obtained by measurements on the radiographs but this is a pure coincidence and is due to the fact that two opposing errors usually cancel one another out In the initial position there is already an unknown flexion which is not measured—in the present cases 7–22 There is then usually a balance of this or a slightly larger angle when maximum flexion is performed since then the rotation of the pelvis is

tion de la hanche a été développée sur la base de l'analyse radiographique de la mobilité de la hanche et du bassin durant des manipulations variées. Les valeurs obtenues par cette méthode concordaient étroitement avec les trouvailles de l'examen radiographique. La méthode montre que l'étendue sagittale de mobilité varie entre 107° et 178° chez le sujet normal et qu'elle diminue avec l'âge.

ZUSAMMENFASSUNG

Eine Untersuchung des Bewegungsausmasses des Hüftgelenkes wurde ausgeführt. Diese wurde mittels der gangbaren Methode von Thomas, der Methode von Milch und mittels Messungen an den Röntgenbildern bestimmt. Die Untersuchung wurde an 95 normalen Personen und in 10 Fällen von Osteoarthritis vorgenommen. Man fand, dass die Methode von Thomas zu hohe und die Methode von Milch zu niedrige Werte ergiebt. Eine neue Methode zur Untersuchung der Beweglichkeit des Hüftgelenkes auf Grund einer röntgenologischen Analyse der Beweglichkeit des Gelenkes und des Beckens während verschiedener Manipulationen wurde daher entwickelt. Die Werte, welche mit dieser Methode erhalten wurden, stimmen mit den Befunden der Röntgenuntersuchung gut überein. Die Methode zeigte, dass der Bewegungsumfang in der Sagittalebene bei normalen Personen zwischen 107° und 178° variiert und dass er mit zunehmendem Alter abnimmt.

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From Sophies Minde Oslo University Orthopaedic Hospital
(Head Professor dr med Ivar Alvik)

TIBIA VARA (OSTEOCHONDROSIS DEFORMANS TIBIAE OR BLOUNT S DISEASE)

Treatment and Follow up Examination

By

INGULF MEDBO

This disease was first mentioned in the literature by *Erlacher* in 1922 Since then many cases have been described particularly by Scandinavian authors

In 1937 W P *Blount* collected 23 previously published cases added 13 of his own and gave a clinical histological and roentgenological description of the condition

Since then it has been considered as a disease entity with the name suggested by *Blount* Tibia Vara or Osteochondrosis Deformans Tibiae Subsequent literature included *A Langenskiold* s valuable contributions both clinical and by animal experimentation

SYMPTOMS

Both *Blount* and *Langenskiold* describe an infantile and an adolescent group of patients The infantile group consists of cases in which the varus deformity appears most frequently in the second year of life In the adolescent group the varus deformity does not appear until the age of 6 to 8 years

The dominating symptom is the varus position of one or both knee joints where the deformity appears as a marked angulation at the proximal end of the tibia (Fig 1)

Other symptoms and signs which may be present are pain in and instability of the knee joint increased medial tortion of the leg compensating planovalgus deformity in the foot and a shortening of the tibia



Fig 1
Blount's disease Girl 2½ years old (Case I K)



Fig 2



Fig 3

Fig 2 X ray appearance of Blount's disease Girl 2 years old (Case I K)—Note the normal outline of the epiphysis

Fig 3 X ray appearance of Blount's disease Girl 6½ years old (Case R J) Note that the deformity also includes the medial part of the epiphysis

Figs 2 and 3 show typical X ray findings in children with *Blount's* disease

Histological examination of tissue taken from the medial part of the proximal metaphysis shows coarse irregular trabeculae with islands

of cartilage interspersed The normal columnar arrangement of the cells in the epiphyseal cartilage will be lacking

PRESENT CASES

Our series consists of 17 patients treated at Sophies Minde Oslo University Orthopaedic Hospital during the period 1944–1961

In Table 1 is found a survey of the 17 patients 16 girls and one boy There are 13 bilateral and 4 unilateral cases 8 patients were operated once 5 patients twice and 4 patients three times In all 50 operations were performed on 30 affected extremities

It may be of interest to note that in 2 patients during the observation period we found clinical and roentgenological signs of increased anteversion in collum femoris to such a degree that rotation osteotomy was indicated

SURGICAL TECHNIQUE

The above mentioned 50 operations performed to correct the varus deformity in the knees were carried out over a long period of time from 1945–1961 A number of different surgeons have performed the operations and the technique has varied

In the majority of cases an ordinary wedge osteotomy proximally on the tibia was done In those cases where the torsion deformity was particularly severe a simultaneous torsion correction was carried out

During the first years no other post operative fixation than a plaster cast was used Because of sliding in the osteotomy area in a few cases fixation with one or more Blount staples was subsequently adopted Our present technique which was used in the majority of cases is as follows The fibula is exposed in a separate lateral incision below the collum A section 1 cm in length is resected subperiosteally Two longitudinal incisions slightly curved give good access to the proximal end of the tibia from both sides A wedge is removed on the lateral side of the tibia a little below the epiphyseal line the base of the wedge posterolaterally The wedge includes approximately 2/3 of the diameter of the tibia The rest of the diameter is cut straight through It is now possible to correct the malposition in the frontal plane as well as torsion abnormalities In the opening medially and anteriorally a bone graft is inserted (autotransplant) The corrected position is fixed by means of two or three staples (Fig 4)

This method has resulted in few or no complications very satisfactory correction and rapid healing of the bone

TABLE 1

Data Collected from the 17 Cases which are Included in the Material

Initials	Born	Sex	Unilat or bilat affection	Age yrs: Deformity observed first time	Age yrs: Definite diagnosis	Deformity before operative treatment Rt	Deformity before operative treatment Lt	Age yrs: First operation Rt	First operation Lt	Second operation Rt	Second operation Lt	Third operation Rt	Third operation Lt	Complications
RJ	1949	♀	Bil	1	7	Va 10	Va 15	7	7	17	13			
KMK	1949	♀	Bil	1½	3	Va 4	Va 6	3½	3½					Recurvation rt leg Reop
ME	1942	♀	Bil	1½	9	Va 28	Vg 1	9	9	16	16			
MN	1943	♀	Dx	1½	12	Va 12		12						
CM	1943	♀	Bil	1½	4	Va 12	Va 21	4	4	16	16			
AK	1943	♀	Sin	1½	8	Vg 4	Va 13		17					
BK	1944	♀	Sin	1½	4	Vg 4	Va 6		4					
LKW	1944	♀	Dx	1½	5	Va 4		3						
IR	1944	♀	Bil	1½	11	Va 2	Va 4	11	11	16	16		18	Post opr paresis
VC	1945	♀	Bil	1½	8	0	Va 5		9					
LK	1946	♀	Bil	1½	1½	Va 20	Va 27	3	3					
KF	1948	♀	Bil	1½	1½	?	Va 11	5	5	9	9	11	11	Post opr paresis n fib lx + recurvation Reopr
IJK	1948	♀	Bil	1½	7	Va 26	Va 2	7		11		13		
TI	1950	♀	Bil	1½	1½	Vg 6	Va 11		8	11	11			
AMR	1951	♀	Bil	6	9	Va 4	Va 3	11	10					
HSA	1951	♂	Bil	1½	4	Va 47	Va 57	5	5	8	8	11	11	
CH	1951	♀	Bil	1½	4	Va 15	Va 15	6½	6½	8	8			Post opr paresis n fib dx



Fig 4

Postoperative X-ray of Blount's disease. Girl 10 years old (Case 71). Note fixation with Blount staples and bone graft medially.

COMPLICATIONS DUE TO OPERATION

We have had two types of complications following this operation. One is sliding between the two fragments, the other is paralysis of the fibular nerve.

Sliding has not occurred since we started using fixation with staples in addition to a plaster-cast.

We have not had any case of fibular paralysis since we started resection of the fibula through a separate incision on the lateral side.

Delayed union has never been observed.

RESULTS OF THE TREATMENT

A survey of the present cases reveals that only in a few cases has permanent correction been obtained by a single operation. This is not surprising since the operation only entails a mechanical correction and influences neither the disease itself nor its cause.

Consequently, in evaluating the results it is necessary to follow the patient from the onset of the first symptoms until the epiphyses are closed at the approximate age of 16.

It was therefore decided to present the results of treatment only of patients who had reached the age of 16 at the follow-up examination in 1962.

TABLE

Data Collected from 11 Cases at Follow up

Initials	Sex	Affection	Position of knee before treatment		Number of operations		Age at first operations		Follow up				
									Age	Subjective discomfort		Physical activity	R mot n k j nts Rt Lt
			Rt	Lt	Rt	Lt	Rt	Lt		Rt	Lt		
RJ	♀	Bil	Va 10	Va 15	2	2	7	7	20	—	—	Full	Normal
LK	♀	Bil	Va 29	Va 27	1	1	3	3	18	—	—	Full	Normal
BK	♀	Sin	Vg 4	Va 6		1		4	18	Slight			
KMK	♀	Bil	Va 4	Va 6	1	1	3	3	20	—	—	Full	Normal
LKW	♀	Dx	Va 4		1		3		18	—	—	Full	Norma
VC	♀	Bil	0	Va 5		1		9	17	—	—	Full	Norma
MN	♀	Dx	Va 12	?	1		12		19	—	—	Full	Norma
CM	♀	Bil	Va 12	Va 21	2	2	4	4	19	Slight		Full	Norma
IB	♀	Bil	Va 2	Va 4	2	3	11	11	18	—	—	Full	
MI	♀	Bil	Va 28	Vg 1	2	2	9	9	20	—	—	Full	Norm
AK	♀	Sin	Vg 4	Va 13		1		17	18	—	—	Full	Norm

Table 2 contains a description of these 11 patients All are female 7 affected bilaterally and 4 unilaterally 7 are operated once 3 are operated twice and 1 operated three times on the left side and twice on the right side

At the time of the follow up examination all patients were between 16 and 20 years old 10 were examined by the author while information about the 11th is based on written information from the patient

a *Symptoms*

9 patients reported that they have no functional discomfort in the knees 2 reveal that they have slight discomfort from one knee in the nature of stiffness in the joint and muscle pain in the thigh following strenous activity One of these has increased anteversion of the femoral neck It is noteworthy that none have discomfort which keeps them from any physical activity common to their age group

Regarding the cosmetic result 8 patients report that they are satisfied 3 are dissatisfied

b *Signs*

(Only 10 patients were examined by the author)

Normal range of motion can be observed in all those examined Only

fter Closing of the Epiphyseal Plate

mination												
Position of knees after treatment		Torsion deformity of leg		Instability of knee joint		Cosmetic result	Shortening of legs		X-ray deformity of knee joint		Function cosmetic and prognostic result
Rt	Lt	Rt	Lt	Rt	Lt		Rt	Lt			
g 5	Vg 4	—	—	—	—	Good	—	—	—	+	Good
g 3	Vg 5	—	—	—	—	Good	—	—	—	—	Excelle
						Fair					
g 1	Va 1	—	—	2	4	Good	—	—	—	—	Good
g 2	Vg 1	—	—	—	—	Good	—	—	—	—	Excelle
g 1	Vg 2	—	—	—	—	Good	—	1 cm	—	—	Good
a 4	Vg 5	+	—	2–3		Fair	1.5 cm	—	—	—	Fair
g 8	Vg 5	+	—	3	2	Good	—	—	—	—	Good
g 11	Va 2	+	—	2 3	3–4	Good	—	—	+	++	Good
g 11	Va 2	—	+	2	—	Fair	—	—	++	+	Fair
g 4	Vg 2	—	+	—	2 3	Good	—	1 cm	—	+	Fair

4 have normal stability of the knees while the remaining 6 have a slight degree of instability upon weight bearing.

5 of 10 have normal leg torsion. The others have increased medial torsion in one or both legs. The length of the legs is the same in 7 while 3 have shortening of one affected leg varying from 1–1.5 cm.

Upon roentgenological examination a satisfactory degree of valgus was found in 7 of the 10 patients.

The remaining had varus position varying from 0–4 degrees in one or both knees. It may also be mentioned that 4 patients had an incompletely developed medial tibial plateau roentgenologically judged.

Considering all the above mentioned signs and symptoms one is left with the impression that in only 2 of the cases have completely satisfactory results been obtained. In 5 cases the result must be considered satisfactory while 3 cases are not completely satisfactory. In the latter cases arthrotic changes in the knee at a comparatively young age must be anticipated.

As shown in Table 3 one finds at present in 2 patients a range of rotation of the hip joints which indicates increased anteversion of the neck of the femur, an observation which is confirmed by roentgenological observation. A corrective rotation osteotomy was performed earlier on one patient.

TABLE 3

Range of Rotation of Hip-joints at Follow up Examination

		Range of rotation of hip-joints in degrees		
			Rt	Lt
LK	18 years	Internal	60	60
		External	30	30
RJ	20 years		Unknown	
VC	17 years	Internal	45 —	25
		External	30 —	50
CM	19 years	Internal	85 —	85
		External	0 —	0
JR	18 years	Internal	70 —	70
		External	20 —	20
KMK	20 years	Internal	70 —	70
		External	35 —	35
MN	19 years	Internal	70 —	60
		External	10 —	20
MF	20 years	Internal	90 —	5
		External	5 —	50
LKW	18 years	Internal	60 —	65
		External	40 —	35
AK	19 years	Internal	65 —	60
		External	40 —	35
BK	18 years		Unknown	

Rotation osteotomy performed

Untreated slipped epiphysis lt femoral neck

DISCUSSION

1 *Clinical Classification of the Patients*

In the present series the diagnosis is frequently not established with certainty until the children are 6 years old or more but we have reliable information that varus has been present from the age of 1 2 years This pertains to all patients except one In this case the information regarding the first years was indefinite The subsequent course would indicate that this patient too belongs in the infantile group It therefore seems reasonable to assume that in this series which has been collected over a period of years all cases must be included in the infantile group

2 *Clinical Signs and Symptoms*

It is evident from the case histories of our patients that until the age of 6 the varus deformity is the only subjective symptom of the disease

Only in children 6 years old or more are there complaints of pain and instability of the knees and not until this age will a difference in length develop which is of functional importance

One must therefore assume that the subjective symptoms in Blount s disease imply a comparatively longlasting weight bearing in varus position of the knee

This is undoubtedly of importance for the choice of treatment A varus deformity ought to be corrected surgically before the subjective symptoms appear Longterm weight bearing in varus should be avoided

3 *Etiology*

During treatment of our patients with genu varum one noticed many years ago that the deformity of the knees in some of the patients was combined with an increased anteversion of the femoral neck In two cases the operative correction of the malposition of knees was supplemented with a rotation osteotomy performed below the trochanter of the femur

At the follow up examination one found in addition to these two patients clinical signs of increased anteversion in one patient and also one patient who had this deformity in the right hip combined with an untreated epiphyseolysis in the left hip joint

The high frequency of increased anteversion in the present study may suggest that the two deformities have common etiological factors a hypothesis which receives support from other observations

4 *Method of Operation and Related Complications*

In the literature one finds a surgical technique described in which the tibia osteotomy is performed along an inclined or curved plane This should lead to a more successful correction of the varus as well as the torsion deformity Our surgical technique which has been described previously is easy to perform and in our opinion the resulting correction is entirely successful

5 *Late Results of Treatment*

At the time of the follow up examination an attempt was made to answer many different questions concerning the knees and lower extremities of the patients

The sum total of these evaluations forms the basis for the following classification of the final result (see Table 2)

Excellent	2
Good	5
Fair	3

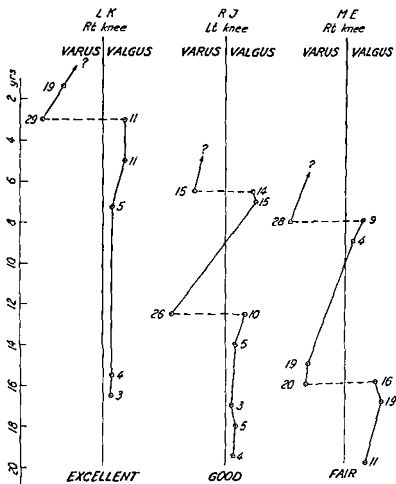
In this connection Excellent means that the patient had no sequela whatsoever following the disease

Good means that the patient herself is satisfied but that examination may reveal mild sequela

Fair means that the patient as well as the medical examiner notice mild sequela Functionally speaking these sequela are of no importance at present but one predicts that they may lead to early arthrosis in the knees

TABLE 4

Spontaneous and Operative Change in Axis of Knee-Joint in Three Patients



In Table 4 an attempt is found at a graphic presentation of the course of the disease in one patient from each of the 3 groups Excellent Fair and Good

For the sake of clarity only one knee from each patient is included This graphic presentation well illustrates the information revealed by the follow up examination

Excellent We achieved this result by early correction and by consistently maintaining the knee in a valgus position

Good This result was achieved when the first correction was not performed until the age of 6 or 7 and when the second correction was delayed until an extensive varus had developed

Fair This result was achieved when the first corrective operation was performed at the age of 8 or 9 and when afterwards the patient was exposed to longlasting weight bearing in varus position This conduct of the treatment easily leads to a permanent deformation of the medial part of the knee joint

6 *Conservative Treatment*

In our series there are no cases treated conservatively In progressive Blount s disease the conservative treatment must of necessity be of long duration It ought perhaps to be combined with nonweight bearing of the affected extremity Under these conditions it is doubtful whether conservative treatment is from the patient s point of view preferable to surgical treatment even though during the growth period 2 or 3 osteotomies may be necessary

On the other hand in milder cases the patient is treated according to the subsequent development Not until definite progression is established is surgical correction indicated Mild cases with spontaneous remission need scarcely any treatment but should be kept under close observation

SUMMARY AND CONCLUSIONS

A series of 17 patients with Blount s disease was followed through the period of growth All patients were surgically treated

At the last follow up 11 patients had reached the age of 16 when the epiphyseal plate was closed and a final evaluation of the treatment was made possible

Admittedly the small number of patients somewhat limits the [illegible] of general conclusions which may be reached on the bas[illegible]

reported results With this reservation the following suggestions for the treatment plan in cases with Blount s disease may be given

1 As soon as the diagnosis is made with certainty and the disease seems to be progressive surgical correction of the varus position should be performed at an early age (3–4 years)

2 If the disease shows further progression reoperation should be carried out at such short intervals that the patient will not have weight bearing in varus position of the knee joint for any length of time

3 When operating one should try to achieve sufficient overcorrection (10–20 degrees valgus) In this way one prevents two injurious factors from simultaneously deforming a growing joint the osteochondrosis on one side and the weight bearing in varus position on the other

4 During the treatment period one should be aware of the possibility of a simultaneously appearing increased anteversion of the femoral neck which may require treatment

RESUME ET CONCLUSIONS

Une serie de 17 malades atteints de la maladie de Blount ont ete suivis durant la période de la croissance Tous les malades avaient ete traites chirurgicalement

Au dernier examen 11 malades avaient atteint l age de 16 ans c est a dire le moment ou la plaque epiphysaire est close et ou il est possible de faire une evaluation finale du traitement

Il faut reconnaitre cependant que le petit nombre des malades limite la valeur des conclusions générales auxquelles on peut arriver sur la base des resultats rapportes En prenant cette reserve les suggestions suivantes peuvent etre faites concernant le plan de traitement des cas de la maladie de Blount

1 Aussitot que le diagnostic a ete pose avec certitude et que la maladie paraît progresser il convient de pratiquer une correction chirurgicale en position varus a un age precoce (3–4 ans)

2 Si la maladie semble poursuivre sa progression une réoperation doit etre pratiquée a intervalles assez courts pour que le malade n ait pas a supporter le poids du corps en position varus de l articulation du genou pour une dures quelconque de temps

3 En pratiquant l operation il convient de donner une surcorrection suffisante (10–20 degrés valgus) De cette maniere on evite deux facteurs prejudiciables pouvant simultanement deformer une articula

tion en croissance d'un cote l'osteochondrose de l'autre le poids du corps en position varus

4 Durant la periode du traitement on doit songer a la possibilite de l'apparition simultanee d'une anteversion accrue de la tete femorale qui pourrait exiger un traitement

ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN

Eine Reihenfolge von 17 Patienten mit Blounts Erkrankung wird wahrend der Wachstumsperiode verfolgt Alle Patienten waren chirurgisch behandelt worden

Bei der letzten Nachuntersuchung hatten 11 Patienten das Alter von 16 Jahren erreicht in dem die Epiphysenplatte geschlossen ist und eine endgultige Bewertung der Behandlung moglich ist

Selbstverstandlich begrenzt die kleine Zahl der Patienten bis zu einem gewissen Grade den Wert von allgemeinen Schlussfolgerungen die auf Grund der berichteten Ergebnisse erreicht werden konnen Mit dieser Einschrankung konnen die folgenden Vorschlage zur Behandlung der Blount'schen Erkrankung gemacht werden

1 So bald eine sichere Diagnose gestellt ist und die Erkrankung fortschreitend zu sein scheint sollte die chirurgische Korrektur der Varusstellung fruhzeitig vorgenommen werden (mit 3–4 Jahren)

2 Wenn die Erkrankung weiterhin fortschreitet sollte eine erneute Operation in so kurzem Intervall ausgefuhrt werden dass der Patient das Kniegelenk nicht fur längere Zeit in Varusstellung belastet

3 Bei der Operation sollte man versuchen eine genugende Uberkorrektur (10–20 valgus) zu erhalten Dadurch verhindert man zweierlei schadliche Faktoren daran dass sie gleichzeitig das wachsende Gelenk verbilden Die Osteochondrose einerseits und die Belastung in Varusstellung andererseits

4 Wahrend der Behandlungsperiode sollte man auf die Moglichkeit einer gleichzeitig auftretenden vergrosserten Anteversion des Oberschenkelhalses achtgeben die unter Umstanden ebenfalls Behandlung erfordert

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Fig. 1 A *Fig. 1 B* *Fig. 1 C* *Fig. 1 D*

TABLE 1

Case	Sex	Aetiol.	Side	Type of absence	No. of toes	Associated malformations
1 N.L.	male	?	sin.	total	5	Pes aequinovarus et diastasis tibio-fibularis l. dx.
2 M.L.	female	?	dx. sin.	partial partial	4 4	Aplasia radii l.a. Anomalia costae II sin.
3 M.J.	female	?	dx. sin.	total partial	2 4 + 1 anomalous	Anus vestibularis Spina bifida Hernia umbilicalis
4 M.S.	female	Thalidom.	dx. sin.	total total	6 7	Phocomelia extr. sup. l.a. Deformatio sacri

caused by thalidomide; in the others the aetiology remains obscure. One case was unilateral, the rest bilateral. Half the defects were total. There were anomalies of the toes in all but one case. Polydactyly occurred in two cases. The femur was within normal limits in most cases. In this respect the defects of the tibia seem to differ clearly from

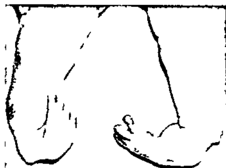


Fig 2 A



Fig 2 B



Fig 2 C



Fig 2 D

fibular defects since the latter are almost always associated with a defective femur (11) As will be seen from the table other malformations occurred in all cases the majority of them being severe This fact of course often affects both the planning of the treatment and the prognosis

TABLE 2

Case	Side	Type	Operation	Age at oper	Time of follow up	Result	
1 N I	sin	tot	1 Subperiostal transplantation of right fibula to site of tibia	3 mo		Knee comparat stable but ankylosis incomplete	Walks satisfactorily with the aid of a brace
			2 Implantation of distal end of fibula (Fig 5)	2 yrs 9 mo		Transplants partially resorbed Fibula tibialized length 50% of contralateral tibia	
			3 Implantation of proximal end of fibula *into* femur	6 yrs		Good ankylosis in ankle Marked equinovarus position	
			4 Transplantation of metatarsal bone to site of tibia	8 yrs			
			5 Transposition of proximal end of fibula	9 5 yrs	13 yrs		
2 M I	dx	part	1 Achillotenotomy	6 mo		Knee stable	Walks well with braces
			2 Autotransplantation of rib	10 mo		Fibula fused with tibial shaft and tibialized	
			3 Implantation *of* distal end of fibula (Fig 5)	14 mo		Good ankylosis in ankle	
			4 *Tibio* fibular osteosynthesis (Fig 6 A)	2 yrs	9 5 yrs	Persisting equinus position Varus position corrected	
	sin	part	1 Achillotenotomy	6 mo		Knee stable	
			2 Implantation of distal end of fibula + tibio fibular osteosynthesis (Fig [illegible] and 6 B)	14 mo	9 yrs	Whole tibia solid down to the ankle slightly bent in medial direction Fibula somewhat atrophied Good ankylosis in ankle varus position corrected Persist equinus position	

TABLE 2 (cont.)

Case	Side	Type	Operation	Age at oper.	Time of follow-up	Result	
3 M.J.	Rt	Tot.	Exarticulation in knee	14 mo	6 yrs	Stump good Configuration and growth of femur normal	Walks excellently with the aid of braces able to run
	Lt	part.	1. Extirpation of supernumerary toes Implantation of distal end of fibula (Fig. 5) 3. Osteotomy of calcaneus 4. Tibiofibular synthesis (Fig. 6C)	4 mo 11 mo 2.5 yrs 3 yr	6.5 yrs	Knee stable Fibula fused to the tibial rudiment and tibialized Good ankylosis in ankle Varus position corrected Persistent equinus position	



Fig. 3.

TREATMENT

Without treatment the knee tends to remain in flexion contracture and the foot is fixed in a marked varus position. In total defect of the tibia, in particular, the possibilities of treatment are very limited owing to the instability of the knee. In these cases amputation is generally considered unavoidable (1, 8, 9, 10). In partial absence of the tibia many surgeons amputate even in early infancy (1). With regard to the age at which amputation should be carried out opinions vary, but most authors are agreed that it should not be undertaken during the early stages of growth, and there are reports in the literature on the problems to which early amputation has led (1, 12). In some cases efforts have been made to correct the malposition by surgery and to create stability of the knee and ankle by making use of the fibula (4, 8). The late results of these procedures have not been described, however.

The operations performed in the present cases are seen in Table 2. Three patients and a total of five limbs were surgically treated. All were presented for treatment when less than 6 months old. In one extremity exarticulation of the knee was carried out. This was a case of extremely severe malformation (Fig. 4–A). In case 2 efforts were at first made to correct the malposition of the foot by achillotenotomy and redression, but with poor results.



Fig 4

In all cases except case 3 (right side) an operation of the type illustrated in Fig 5 was carried out to correct the varus position and to stabilize the ankle The distal end of the fibula was exposed and freed from the surrounding tissues The joint cartilage was excised and the epiphysis made roughly cone shaped The upper surface of the talus was exposed and the joint cartilage excised until a smooth surface was obtained A hole was drilled through the talus to the calcaneus Taut tibial soft tissue strands were divided sufficiently to allow correction of the varus position of the foot and the distal end of the fibula was implanted into the drill hole The fixation was achieved with a Kirschner needle introduced from under the foot through the tarsal bones into the medullar cavity of the fibula The leg was then immobilized for 6 to 8 weeks in a plaster boot The needle was removed two weeks after the operation

In case 3 osteotomy of the left calcaneus was carried out 2 years later to correct the rocking chair shaped deformity of the foot

In total absence of the tibia we tried to construct a bony support at the site of the missing tibia by subperiosteal transposition of the contralateral fibula This was almost entirely resorbed however Then we tried to achieve arthrodesis between the fibula and the epiphysis of the femur Despite several attempts we did not completely succeed

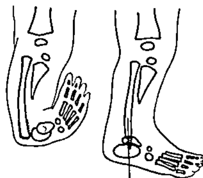


Fig 5

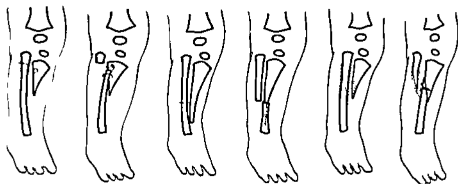


Fig 6 A *Fig 6 B* *Fig 6 C*

In three cases of partial defect we tried to improve the stability of the knee by uniting the fibula with the tibial rudiment A different technique was applied in each case (Figs 6 A–C) In case 2 on the right side the cut proximal end of the fibula was implanted in a hole drilled into the side of the tibia and fixed with metal wire (Fig 6 A) In connexion with the implantation of the distal end of the left fibula in case 2 the fibular diaphysis was cut through and the tibial rudiment implanted into the distal portion of the fibula (Fig 6 B) Fig 2 D makes a comparison of the end results of these operations possible In case 3 the proximal end of the left fibula was cut obliquely and united subperiosteally to the side of the exposed tibial rudiment with a screw (Fig 6 C) Fig 3 C shows the result of this operation

RESULTS

Table 2 shows the results obtained. The time of observation varies between 6.5 and 12 years. Exarticulation of the knee joint carried out in a case of total defect gave a satisfactory result. Despite the normal growth of the femur the stump is well preserved. All other cases were treated by palliative surgery.

In a case of total defect (case 1) the result did not fulfil our expectations. The tibialized fibula constitutes a firm continuation of the femur but the arthrodesis was not quite successful. The pronounced shortening of the tibia renders lengthening by an orthopaedic boot imperative. It is probable that a better walking capacity would be obtained later in this case by above knee amputation and a suitable prosthesis. The deformity of the other leg also impairs the patient's walking. The marked inward rotation of the foot was later corrected by rotation osteotomy of the leg. The weight bearing position of the foot then became satisfactory.

In all cases of partial defect the union of the fibula with the tibial rudiment was successful. The knee is stable in every case. The leg is firm and straight and no significant progressive shortening has taken place. The results of all three operative procedures appear more or less equally good.

Good ankylosis of the ankle and correction of the varus position were achieved in all cases. We did not attempt complete correction of the equinus position which therefore persist in the majority of cases. The foot is in most cases to some extent rocking chair shaped since the dorsal end of the calcaneus tends to be displaced in a proximal direction. In case 3 the left calcaneus was osteotomized in order to obtain a better weight bearing position. The result was excellent.

In all cases walking with the aid of braces is at least satisfactory considering that there is bilateral deformity of the legs in all of them. Despite a prosthesis on one leg patient no. 3 is even capable of running.

DISCUSSION

In total defect of the tibia ultimate amputation seems to be the method of choice to judge from the present cases. The final result will depend to some extent on the site of the amputation and the age at which this measure is carried out. In practice the final level of the amputation will be above the knee. If this is done at a very early age

however very marked shortening of the stump must be expected We know from earlier investigations (2) that the distal epiphysis of the femur is responsible for over two thirds of the growth of this bone Thus the result may well be the same as in amputation at the middle of the femur Exarticulation of the knee or palliative operations do not *interfere with the normal growth of the femur* In the latter case several operations may be required and a suitable brace must be applied In these cases the details of the final amputation should be decided with a view to achieving a good stump

In partial defects good stability of the knee can always be obtained A firm and normally growing leg can be achieved by making use of the fibula In partial absence of the tibia amputation is not to be recommended A good weight bearing position of the foot can be achieved by implantation of the fibula in the ankle bones Even though the equinus position is not completely corrected it does not appreciably impair walking if an orthopaedic boot is used After cessation of growth it is possible finally to correct the position should this be considered necessary

The tibial defect seems to be bilateral in most cases This fact naturally renders treatment still more difficult Case 3 however shows that the functional result may be quite satisfactory even in very severe cases

Numerous severe accessory deformities further complicate the problem of treatment However recent advances in pediatric surgery have improved the prognosis in many ways

When the order of importance of the various measures of treatment are contemplated it must be remembered that to make it possible for the child to move is of paramount importance for its mental and social development

SUMMARY

On the basis of a series of four patients with a total of seven extremities with a tibial defect the clinical picture and the methods of treatment of congenital absence of the tibia are discussed Half the defects were partial Five limbs were treated operatively In one case of total absence of the tibia exarticulation of the knee was carried out at an early age while another was treated with palliative operations The authors are of the opinion that in cases of total defect amputation will give the best result but that above knee amputation should be postponed until growth is complete Three partial defects were treated by implan

tation of the distal end of the fibula in the ankle bones and by uniting the fibula with the tibial rudiment From the point of view of weight bearing a good result was obtained in all cases and the patients are capable of walking well with the aid of a brace despite their bilateral defects The authors do not recommend amputation in these cases

RESUME

Sur la base d une serie de quatre malades avec un total de sept extremités présentant un defaut du tibia le tableau clinique et les methodes de traitment de l absence congenitale de tibia sont discutees Dans la moitie des cas le defaut etait partiel Cinq membres furent operes Dans un cas il y avait absence totale du tibia Une exarticulation du genou a ete pratiquee a un age precoce Les autres cas ont ete traites par des operations palliatives Les auteurs sont d avis que dans les cas de défaut total l amputation au dessus du genou donne le meilleur resultat a condition d attendre jusqu au moment ou la croissance est achevee Trois defauts partiels ont ete traites par implantations de l extremite distale du femur dans les os de la cheville et par l union du femur au rudiment tibial

Un bon resultat a ete eobtenu par rapport au support du poids dans tous les cas et les malades sont capables de bien marcher a l aide d une attelle malgre leur defaut bilateral Les auteurs ne recommandent pas l amputation dans ces cas

ZUSAMMENFASSUNG

Auf Grund einer Reihenfolge von vier Patienten mit insgesamt sieben Gliedmassen mit einem Tibiadefekt werden das klinische Bild und die Behandlungsmethoden des angeborenen Fehlens der Tibia erortert Die Halfte der Defekte war teilweise Funf Gliedmassen wurden operativ behandelt In einem Falle von vollkommenen Fehlen der Tibia wurde eine Exartikulation des Knies im fruhen Alter ausgefuhrt wahrend ein anderer mit palliativen Operationen behandelt wurde Die Verfasser sind der Ansicht dass in Fallen von vollstandigem Defekt eine Amputation die besten Resultate ergeben wird dass aber Amputationen oberhalb des Knies bis zum vollendeten Wachstum verschoben werden sollten Drei teilweise Defekte wurden mittels Implantation des distalen Endes der Fibula in die Knockelknochen und mittels Vereinigung der Fibula mit dem tibialen Rudiment behandelt Was die Belastung an

belangt so wurde in allen Fällen eine gutes Resultat erzielt und die Patienten gehen gut mit der Hilfe von Schienenapparaten obwohl sie einen doppelseitigen Defekt haben Die Verfasser empfehlen nicht die Amputation in solchen Fallen

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ANGULAR VARUS DEFORMITY IN THE DISTAL END OF THE TIBIA

By

PAULI TORPPI and PENTTI HANNINEN

In Vaasa provincial hospital 2 children were seen both of whom had an angular varus deformity at the distal end of the tibia clinically completely similar in appearance In one of the cases it was caused by severe rickets in the other the etiology was obscure In medical literature we have not found descriptions of similar cases

Tibia vara a nonrachitic deformity appearing in the upper end of the bone was defined as a disease in itself by *Blount* (1937) He also gave it the name osteochondrosis deformans tibiae Many cases had earlier been published under different names The etiology of tibia vara is unknown It has been considered an aspetic bone necrosis or something comparable with it (*Nilsonne* 1929 *Blount* 1941) but on the other hand microscopic studies have shown changes in the cartilage only and not in the bone (*Langenskiold* 1952) Obesity has often appeared in connection with the infantile type of tibia vara (*Langenskiold*) *Barber* (1939) has presented a case in which there was varus deformity in both ends of the tibia but not in the diaphysis However the X ray changes of the distal epiphysis were slight and the case in question is not of the same type as our case No 1 There is still a rare congenital varus deformity where bending occurs in the distal third of the tibial diaphysis The narrowing of the diaphysis of the tibia and the higher density at the bent point without epiphyseal changes can the be seen in X ray pictures (*Blount* (2) *Langenskiold*)

Multiple ossification centres (*Christensen* 1955) and irregularity of ossification (*Fairbank* 1947 *Leeds* 1960) are seen in dysplasia epiphysealis multiplex This disease is generally hereditary (*Waugh* 1952 *Christensen* *Maudsley* 1955 *Shephard* 1956 *Barrie* 1958 and *Leeds*) and according to *Maudsley* does not appear in early childhood The

patients discussed in books dealing with the subject have been older between 4–50 years (*Christensen, Freiberger* 1958 *Leeds*) These patients are usually of short stature or of stunted growth and have short and clumsy fingers (*Fairbank, Maudsley Barrie*) In our opinion our own case No 1 does not belong to the category discussed in which it is true different forms of the disease appear

Rachitic bow legs are nowadays rare Sometimes rachitic deformity appears although the child has had the customary vitamin D prophylaxis Our second case belongs to this category Renal intestinal hormonal and enzymate factors of many kinds and also the so called vitamin D resistant rickets (*Pedersen & McCarroll* 1951 *Hepp* 1961) among which it is true renal rickets is also often included should be taken into consideration as etiological factors In our case the cause was intestinal Vitamin D in fat soluble form was not sufficiently absorbed The deformity may clinically be the same in appearance both in rachitic and nonrachitic cases

OUR OWN CASES

Case No 1 Girl 13 months old The general development was good Started walking at the age of 8 5 months When the child had been walking for some time the parents found that the legs of the child were bowing into varus No other symptoms indicated ricket Calcium phosphorus and alkaline phosphatase in the blood were normal

Symptomata localis Severe varus deformity in the lower par of each leg Nothing special in other joints

X ray status see Figs 1 a b and c

Treatment Osteotomia sphaerica tibiae et correction et osteotomia fibulae l dx Osteotomy was performed in the metaphysis near the epiphyseal line Varus deformity was corrected easily after osteotomy Plaster was applied

After 6 days the same operation was carried out on the left side

Decursus morbi change of plaster after 1 month Weight bearing was not allowed See Figs 2 a and b taken 1 month after the operation

The plaster cast was removed after 4 months weight bearing was started See Fig 3 which was taken later on and in which complete recovery has been achieved

Case No 2 A baby girl 18 months old She was given codliver oil from the age of 3 months not always regularly started standing at the age of 9 months After that her legs began to bow into varus She started walking at the age of 16 months

Cranium the anterior fontanel was about 1 × 1 cm sutures closed no craniotabes Thorax normal Harrison s groove of hardly noticeable size Calcium in the blood 9 3 mg% phosphorus in the blood 5 1 mg% Alkaline phosphatase in the serum over 10 B L units

Symptomata localia Severe angular varus deformity in the distal parts of each leg Nothing special in other joints X ray status see Fig 4

Treatment Osteotomia sphaerica tibias cum correctio et ostectomia fibulae l sin



Figs 1 a b and c

Case 1 Distal epiphysis of each tibia is irregular and displaced backwards and medially The medial part of the epiphysis of femur is deformed



Figs 2 a and b

Ca[illegible] 1 P[illegible]t[illegible]r[illegible] were taken about 1 month aft[illegible] [illegible]peration Varus def[illegible]rmit[illegible] i[illegible] di[illegible]appearing epiph[illegible] and epiph[illegible]al lin[illegible] are indistinctly vi[illegible]ible



Fig 3

Case 1 Picture was taken 2 years after operation at which time the child was 3 years old Distal epiphysis and epiphysial line of tibia are normal in appearance Function of limbs is normal



Fig 4

Case 2 Epiphysial lines of both femur and tibia are ragged and have become broader The distal epiphysial line of the tibia is deformed and spread out fanwise Severe varus deformity Diagnosis rickets



Figs 5 a b and c

Case ? Picture were taken about 2 months after operation Epiphy ial lines ha e become comparativel regular Still some varus def rmity and antecurvatum in the diaphysis of tibia



F g 6

Case Varu d f rm t ha di app r d b t till ante urv tum in the diaphy i of t bi Epiph si an I piphy i l li seem n rmal

Osteotomy was performed on the cranial side of the epiphysial line Varus deformity was corrected and a plaster cast was applied In addition oral antirachitic treatment *with water soluble vitamin D and with calcium was given*

An operation of the same kind was performed after 6 days on the right side

Decursus morbi Change of plaster after 2 months

See Figs 5 a b and c taken 2 months after the operation

The limbs were in plaster for over 4 months after which the child was allowed to start walking The patient received antirchitic treatment at the time Fig 6 was taken 2 years and 2 months after the operation

DISCUSSION

Gordon (1961) presented a series of radiographs of the legs of a child who at the age of nearly 1 year had marked bowlegs In addition to that at the age of 1½ years some changes had appeared in the distal epiphysis of the tibia and in the distal part of the metaphysis The changes decribed by *Gordon* resemble in some respects our own case No 1 *Gordon* considers the deformity congenital but in our opinion the radiographical appearance is suggestive of rickets

Our own case No 1 differs from the case referred to above in that the diaphysis of the tibia is straight and the ossification in the epiphyseal region is irregular In these respects the case differs from rickets as does Blount s disease We do not know the etiology in case No 1 and we cannot exclude the possibility that the patient had had an early rickets as a result of which the distal epiphysis of the tibia remained weak

By comparing cases No 1 and No 2 with each other we can state that the formed recovered more rapidly In case No 2 recovery was slower in spite of medication and some antecurvatum deformity remained in *the diaphysis of the tibia* However the result of treatment in each case is to be considered good

SUMMARY

Two cases of severe varus deformity in the distal epiphysial area of the tibia in children are discussed The etiology in one case was rickets caused by intestinal malabsorbtion The etiology in the other case was obscure We cannot with certainty exclude the possibility that the patient had had an early rickets as a result of which the distal epiphysis of the tibia remained weak On the other hand this case suggests the possibility that a non rachitic deformity similar to tibia vara (Blount s disease) may occur in the lower end of the tibia Both cases were cured by osteotomy

RESUME

Deux cas de deformite varus grave dans la region epiphysaire distale du tibia chez des enfants sont discutes L etiologie dans un cas etait un rachitisme cause par une mauvaise absorption intestinale L etiologie etait obscure dans l autre cas On ne peut exclure avec certitude que le malade n avait pas souffert de rachitisme precoce d ou il etait resulte que l epiphyse distale du tibia etait restee faible D un autre cote ce cas laisse entrevoir la possibilite qu une deformite non rachitique similaire au tibia varus (maladie de Blount) peut se produire dans l extremite inferieure du tibia Les deux cas ont ete gueris par osteotomie

ZUSAMMENFASSUNG

Zwei Falle von schwerer Varusdeformität in der distalen Epiphysenregion bei Kindern werden besprochen Die Athiologie war in einem Falle Rachitis die infolge intestinaler Malabsorption entstand Die Athiologie in dem anderen Falle war unklar Wir konnen nicht mit Sicherheit die Moglichkeit ausschliessen dass der Patient eine frühzeitige Rachitis gehabt hat mit der Folge einer zuruckbleibenden Schwache der distalen Tibia epiphyse Andererseits jedoch deutet dieser Fall auf die Moglichkeit hin dass eine nicht rachitische Deformitat ähnlich wie die Tibia vara (Blounts Erkrankung) auch am unteren Ende der Tibia vorkommen kann Beide Falle wurdens mittels Osteotomie geheilt

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NON-TREATED TIBIA DEFECT WITH AN EXCELLENT FUNCTION AND WORKING CAPACITY

By

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The article discusses a tibia defect caused by a fracture resulting from a gunshot wound during the war and never corrected surgically. By the patient's own effort and self-rehabilitation the defect had healed so well despite permanent nonunion that the patient not only walks without any orthopaedic aids but is capable even of surprising performances at work and sports. The case was discovered by coincidence when the patient was hospitalized after a traffic accident.

The patient, a man born on August 20, 1915, was wounded in the war (Jan. 14, 1940) at the age of 24 in the right leg by a machine-gun bullet. The bullet entered the posterior surface of the upper third of the right leg, crushed the tibia and formed a gaping wound in the anterior surface of the leg at the same level. Four days later the wound was explored in hospital and the loose bone fragments were removed. The comminuted tibia fracture was immobilized in a plaster cast. The wound was treated locally through a hole in the plaster, but it still required surgery. At three months a fair amount of necrotic bone was removed, after which suppuration soon ended and the wound closed through granulation. The patient's general condition remained good and he moved about on crutches. The plaster cast was finally removed 9½ months after the injury. The fracture was still unstable and the X-ray picture showed a 5 cm long defect in the upper third of the tibia, but the fibula was intact (Fig. 1). Once the plaster cast had been removed the mobility of the knee was soon restored, but that of the ankle remained largely restricted.

After this stage there appeared difficulties in the further care of the patient. He found it very difficult to adapt himself to the long period of hospitalization and he gradually became so difficult to control that



Fig 1

Roentgenograms of the earlier phases of the tibia defect A A-P and lateral projections 10½ months after the wound (Nov 28 1940) B state 3 years after the wound (Nov 21 1942)



Fig 2

The present status (May 9 1962) over 22 years after the wound The corresponding projections of the healthy limb are shown also The picture reveals the filling of the defect with the approach of the fractured parts development of an intermediate fragment and proximal shift of the capitulum fibulae Attention is also attracted by the marked hypertrophy of the fibula of the injured limb

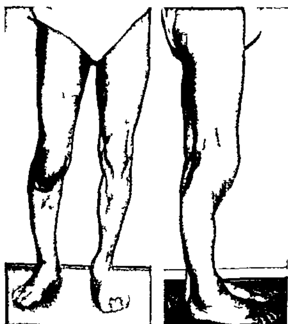


Fig 3

Photograph of the patient standing with his weight distributed equally on both lower limbs The shortening of the right leg is distinct

he had to be discharged According to the plan of treatment the intention was to perform an excision of the cicatrix provide a brace and finally to perform a bone graft The patient was re admitted to hospital a few times but due to bad behaviour the plan of treatment could not be fulfilled at all Gradually all attempts at treatment were abandoned and the patient did not even get a brace he remained on his crutches For several years he led a restless life consuming quantities of alcohol His lack of social responsibility finally brought him into contact with the law The patient s hospital record of April 13 1944 in prison contains the following entry General condition good Walks on crutches The wound is closed Normal mobility of the knee mobility of the ankle improved 130 80 Surgery and bone graft were proposed but the patient was not interested

In 194 the patient married and moved to the countryside He gradually began to calm down He occupied himself at home but accepted no work proper for years He still moved on the two crutches but began gradually to lean on the injured limb This was very painful at first but the tenderness decreased gradually as the exercise advanced Bicycle



Fig 4
The drawing shows the extreme positions of movement in the pseudarthrosis in the A-P and lateral directions

riding seemed to strengthen the limb particularly and for exercise the patient rode distances of several tens of kilometres He used crutches for walking up to 1949 when by chance he once noticed that he could do very well without them This increased his enthusiasm for exercise The patient began to walk with a stick and work in the fields and gradually also began to undertake heavy forest work After strenuous exercise or work the injured leg became painful from knee to ankle but a sauna and massage always relieved the pain The patient has never had a permanent or persistent ache He has never taken pain killing drugs from 1950 he steadily reduced his consumption of alcohol until in 1953 he abstained completely With heavy work his condition improved fast He achieved such skills in forest work that he won the logging championship of his commune in 1951 after a very strenuous 5 day competition In 1951 the patient began to walk without a stick even In 1953 a brace was made for him but it felt heavy and clumsy and he never wore it

The patient had also started skiing for exercise and made such good progress that he began to take part in skiing races in 1953 He skied in some twenty events a year up to 1960 including the 15 and 30 km cross country and once the 50 km He took part in general competitions with normal men and did not do badly at all His beautiful cupboard contains a large number of prizes to testify to the success of his enthusiasm for skiing

The patient s present social standing is good He works as a janitor doing all the jobs involved himself

Subjective symptoms—The patient is happy with his present condition The fact that the site of fracture is unstable does not worry him—he is used to it and has adopted the right gait Ordinary walking

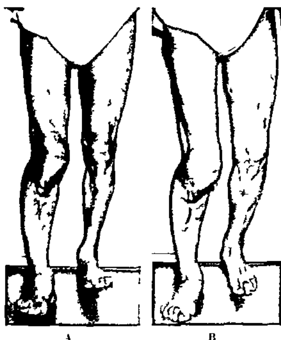


Fig 5

Photographs showing the patient s gait A Right lower limb at the end f the swinging phase before weight was placed on t B The right l wer limb in the supporting pha e of the gait with the patient whole we ght on the right l er limb The marked bending of the pseudarthrotic site and the pr minen of the region of the proximal end f the fibula during the lean ng are clearl ible

causes no pain at all If he has to move about more than usual he feels some pain especially at the proximal tibiofibular joint Sometimes the tibial pseudarthrosis also gives some pain after stress No pain has occurred in the knee or ankle

Present condition —In 1962 22 years after the wound the patient is 47 years old his general condition is good body build well proportioned muscles strong He is 171 cm tall and weighs 67 kg Local symptoms a varus and recurvatum deformity can be seen at the border of the top and middle third of the right leg Abnormal mobility to 25 in the sagittal plane and just over 10 in the frontal plane is also observed (Fig 4) At this height in the posterior surface of the calf there is a small round scar marking the point of entry of the bullet The anterior surface of the leg shows a cicatricial area of 3 × 10 cm The muscles of the right lower limb are not atrophied but it is 3 cm shorter than the fellow limb The right knee shows the full extent of movement The



Fig 6

The pseudarthrotic site when the patient s weight is borne on the right leg The bend and the prominence of the fibular head are distinct when compared with X ray pictures taken without loading (Fig 2)

right ankle shows full plantar flexion but dorsal flexion is restricted by 10 The inversion and eversion of the right ankle are complete The foot and toes are normal Peripheral pulses are felt normal and symmetrical in the limbs No signs of nerve lesion can be found

Function—The patient wears no brace and walks without a stick He limps slightly but can conceal most of the limp by using an easy and elastic gait The patient can negotiate stairs well too When leaning on the right lower limb the pseudarthrosis shows the notable swing illustrated in Fig 5

X ray finding—The study of the roentgenograms reveals how the original tibia defect has filled how it has been possible to achieve the state of weight bearing and how the leg has shortened by 3 cm despite an intact fibula So the following points attract attention

1) The right tibia has a pseudarthrosis at the margin between the top and middle third where the main fragments are joined by a separate fragment to fill the tibia defect (Fig 2) The intermediate fragment has developed from those small pieces of bone seen in the primary pictures (Fig 1)

2) The fibula is heavily hypertrophied The medullar cavity has remained equal in size throughout to that of the left fibula while the



Fig 7

Oblique projection showing the arthrotic changes that had developed in the upper tibiofibular joint osteophytes on the edges of the joint surfaces of both the tibia and the fibula. The abnormally proximal position of the whole joint is also visible. It is surprising that no arthrotic changes are demonstrable in the knee joint or the talocrural joint

corticalis is greatly thickened and shows increased density. In the lateral projection especially the thickening of the fibula is distinct. Measured from the roentgenograms the thickness of the right fibula at the thickest point is 28 mm and that of the left 19 mm. The medullar cavities at this level are 10 mm wide and thus the aggregate thickness of the corticalis is 18 mm on the right and 9 mm on the left. The thickening of the fibula is greatest on the ventral surface but even in the other parts the corticalis of the right fibula is practically throughout twice as thick as that of the left (Fig 2)

3) The right leg is shortened by 3 cm although the fibula is intact. This is possible because of the shift of the capitulum fibulae about 2 cm in the proximal direction at the proximal tibiofibular joint and the lateral arching of the fibular shaft. This shortening of the leg has been a very important factor in the filling of the defect

4) The right knee joint and the talocrural joint show no secondary arthrosis while the margins of the surfaces of the proximal tibiofibular joint show distinct marginal osteophytes (Fig 7)

5) Exposures taken with the patient leaning on the right lower limb

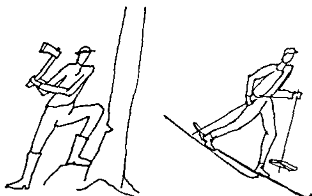


Fig 8

In sharp contrast to the anatomical changes are the patient s remarkable performances at work and sports achieved in general competition with healthy persons

show marked bending in the tibial pseudarthrosis The capitulum fibulae shows a distinct rise proximally under loading its highest point becoming visible above the level of the tibial joint surface while in exposures taken without loading it is below the articular slit (Fig 6)

COMMENT

The subject involved in this case is an exceptional man with a strong will his own attitude and activity have played a decisive role in his vicissitudes But there are also points of general interest associated with the case The primary treatment of the injury was quite routine It obviously helped that so much tissue capable of producing viable bone remained in the area between the fragments that it could form an intermediate fragment to provide an important increase in stability The subsequent progress depended entirely on the patient s own initiative A remarkable self rehabilitation took place which had a surprising outcome

The development of the injured limb to tolerate weight bearing was *the result of the joint action of several structural and functional factors* The fibula was hypertrophied to give the leg adequate strength The proximal shift of the capitulum fibulae curving of the fibular diaphysis and the development of the intermediary fragment overcame the continuity break in the tibia The revived function of the muscles and other soft tissues constituted another natural prerequisite It is striking that the patient overcame the pain and achieved an almost painless condition The change to tolerate weight bearing was a slow process

requiring a great deal of time and effort But this change helped the patient to adopt a new attitude to life and his restored self respect made him again a socially active individual

The end result is anatomically still quite poor Complete stability was not achieved because fairly considerable mobility persisted in the pseudarthrosis The degree of stability that was achieved however sufficed to permit a good functional result The anatomical changes of the proximal tibiofibular joint were accompanied by some secondary arthrosis but it is surprising that the distal tibiofibular union and the talocrural joint remained completely free from symptoms It is also surprising that no arthrosis developed in the knee joint

Rehabilitation alone produced in this case a result that might have been assumed to be impossible without surgery Successful tibiofibular osteosynthesis might perhaps have given better stability But the patient is still not interested in surgical treatment And after all—the purpose of surgery is always only to create the conditions for the achievement of good function

SUMMARY

A case of war injury is reported in which a gunshot wound gave rise to a tibia defect and pseudarthrosis The treatment was given up after the primary stage and the patient was left on crutches However he began a process of self rehabilitation by leaning on the injured limb This had a striking outcome After 9 years the patient walked with the aid of a stick only and after 11 years he even discarded the stick The patient became capable of surprising performances at work including heavy forest work and he took part in some twenty skiing races a year for many years The patient was examined 22 years after the injury It was established that the intact fibula was heavily hypertrophied the tibia defect was filled by an intermediate fragment and the distance between the main fragments was narrowed by shortening of the leg by a proximal shift of the capitulum fibulae in the proximal tibiofibular joint There was still considerable mobility in the pseudarthrosis but the instability had not prevented good function

RESUME

Il est rapporte un cas de blessure de guerre dans laquelle une plaie due a une balle avait provoque un defaut du tibia et une pseudarthrose On avait renonce a poursuivre un traitement apres le stade primaire et

le malade était resté avec des béquilles. Il chercha néanmoins lui-même à procéder à une réadaptation en s'appuyant sur la jambe malade et obtint un résultat étonnant. Au bout de 9 ans le malade marchait avec l'aide d'une canne seulement et au bout de 11 ans il avait même abandonné la canne. Le malade devint alors en état de fournir des prestations surprenantes de travail, y compris de durs travaux forestiers et il prit part à une vingtaine de courses de ski par an durant de nombreuses années. Le malade fut réexaminé 22 ans après la blessure. Il a été établi que le fémur intact était fortement hypertrophié. La partie manquante du tibia était remplie par un fragment intermédiaire, un rapprochement entre les principaux fragments s'était effectué par le raccourcissement de la jambe grâce à une modification proximale de la tête fémorale dans l'articulation proximale tibio-fémorale. Il y avait encore une mobilité considérable de la pseudarthrose, mais l'instabilité n'avait pas empêché une bonne fonction.

ZUSAMMENFASSUNG

Ein Fall von Kriegsbeschädigung wird berichtet, in dem eine Schussverletzung einen Tibiadefekt und Pseudarthrose hervorrief. Die Behandlung wurde nach einem ersten Versuche aufgegeben und der Patient wurde den Krücken überlassen. Er begann jedoch mit einem Vorgehen von Selbst-Wiederherstellung, indem er die beschädigte Gliedmasse etwas belastete. Dies hatte einen unerwarteten Ausgang. Nach 9 Jahren ging der Patient nur mit einem Stock und nach 11 Jahren konnte er den Stock ganz weglassen. Der Patient vollbrachte erstaunliche Arbeitsleistungen, darunter schwere Waldarbeit, und nahm viele Jahre an ungefähr zwanzig Skiwettlaufen jährlich teil. Der Patient wurde 22 Jahre nach der Verwunderung untersucht. Man fandt, dass die intakte Fibula bedeutend hypertrophiert war, der Tibiadefekt war durch ein intermediäres Fragment ausgefüllt und der Abstand zwischen den Hauptfragmenten war durch Verkürzung des Unterschenkels mittels eines proximalen Gleitens des Capitulum fibulae im proximalen tibiofibularen Gelenk verringert. Eine bedeutende abnorme Beweglichkeit in der Psuedarthrose war noch immer vorhanden, aber der Mangel an Festigkeit hat eine gute Funktion nicht verhindert.

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From Sophies Minde Orthopaedic Hospital (Head: Prof. I. Alvik, M.D.)

EXTRA-ARTICULAR SUBTALAR ARTHRODESIS ACCORDING TO GREEN-GRICE IN FLAT FEET

By

ARNE RUGTVEIT

Since *David S. Grice* (1) published in 1952 his study of "An Extra-Articular Arthrodesis of the Subastragal Joint for Correction of Paralytic Flat Feet in Children", this surgical procedure has been much utilized also for flat feet which have no paralytic condition. The use and limitation of the method with paralytic flat feet has been treated by a number of authors (1, 2, 3, 4). The corresponding evaluation of the method for non-paralytic feet has been much less detailed.

It appears from the literature that in this operation with few exceptions autotransplants have been used. *Grice* (2) stated in 1955 that he had used homotransplant in 4 cases. In a series of 52 operated feet resorption of the transplants occurred in one case and in this case homotransplants were used. *Oscar Malnarc* (1) reported in 1960 that he had utilized bone from the bank in 18 cases and obtained osseous ankylosis between the calcaneus and the talus in all cases.

In Sophies Minde Orthopaedic Hospital during the period 1953 to 1960 extra-articular subtalar arthrodeses were performed on 37 flat feet without demonstrable pareses. Homotransplants were used in 34 cases. This material should therefore give a certain basis for evaluating the Green-Grice operation in non-paralytic flat feet and also for evaluating the homotransplant in this connection.

The indication in all cases was a pronounced flat foot with functional symptoms which did not react to active dynamic and static treatment. On average the patient was treated conservatively for 3 years before operative treatment.

. feet could not be satisfactorily redressed preoperatively and during the operation the calcaneus could not be placed in the correct position under the talus. In these cases structural changes were obviously pre-

sent *Grice* (1) stated that in these circumstances he had undertaken capsulotomy or chiselled away bone below and lateral to the talus where it had articular surfaces facing the calcaneus. After reduction stability is tested by means of an osteotome placed in the tarsal sinus. If instability is present *Grice* recommends passing a screw from above through the talus head and down into the calcaneus. This modification was not used in the existing series but could presumably have been indicated in individual cases. Out of 5 cases in which the calcaneus could not be brought into a normal position in relation to the talus synostosis was not achieved in 4 (Table 2). In 2 of these cases however relations with the transplants may have played a part and this problem is further clarified in Table 3.

TABLE 1

Age and Sex Distribution of Patients with Flat Feet Treated by Extra Articular Subtalar Arthrodesis

No of patients operated on	20
Boys	12
Girls	8
No of feet operated on	37
Average period of treatment before operation	3 years
Average age at operation	9.5 years
Average observation period (max 10 years min 2 years)	4 years
Average age at last check up (maximum 18 years minimum 10 years)	13.5 years

TABLE 2

The Redressability of the Feet Pre Operatively in Relation to Osseous Ankylosis Calcaneus Talus Achieved (+) or not Achieved (—). The Figures in Parenthesis State the Number of Feet Operated on where the Transplant is Considered to be Optimal

	No of operated feet	Osseous ankylosis calcaneus talus	
		+	—
Malposition redressible	30 (15)	25 (14)	5 (1)
Short achilles but redressable with slight pointed foot	2 (2)	2 (2)	0 (0)
Full correction not achieved	5 (3)	1 (1)	4 (2)
Sum	37 (20)	28 (17)	9 (3)

Autotransplants were used in only 3 cases. A direct comparison between auto and homotransplants cannot therefore be undertaken here. Within the group in which homotransplants were used a relationship

was found between the characteristics of the transplants and the number used per operation and their ability to produce synostosis between calcaneus and talus. As Table 3 shows, 2 bone blocks were used in 17 cases. Each block consisted of cortical and cancellous bone. In 15 of these 17 cases synostosis was achieved. If we exclude 2 feet which could not be fully corrected the result becomes even better, since the synostosis is then achieved in 14 out of 15 feet operated on (Table 3, heels in brackets).

TABLE 3

The Type of Transplant (Auto, Homo), its Characteristics (Cortical, Cancellous Bone) and the Number per Operated Foot are Demonstrated for Comparison with Osseous Ankylosis Achieved (+) and not Achieved (—) between Calcaneus and Talus. The Figures in Parentheses State the Number of Feet where the Malposition Could be Fully Corrected

	No. of operated feet	Osseous ankylosis calcaneus talus +	—
Autotransplant consisting of 2 bone blocks	3 (2)	3	0
Homotransplant	34 (29)	(24)	9 (5)
2 bone blocks each consisting of cortical and cancellous bone	17 (15)	15 (14)	2 (1)
1 cortical bone block + cancellous bone	11 (10)	7 (7)	4 (3)
1 thick bone plug	6 (4)	3 (3)	3 (1)

In another group of feet 1 bone block was used, fundamentally cortical bone, together with cancellous bone, fundamentally as bone chips. Here synostosis was only obtained in 7 out of 11 feet. This tendency towards decline is somewhat improved, however, if the one not reducible foot in this group is excluded.

In a third group in which 1 thick bone plug was used, most often taken from an ulna, there was also found a considerable tendency towards a decline. Lasting ankylosis was achieved in 3 out of 6 feet operated on. If, however, the not reducible feet are also excluded here, lasting ankylosis was achieved in 3 out of 4 operated on.

No complications occurred in any case in connection with the operation. Each case was treated in plaster for 12 weeks. The majority commenced gradual weight bearing from 8 weeks.

As Table 2 shows, lasting osseous ankylosis was obtained in 28 out

of 37 operated feet However a synostosis between calcaneus and talus does not automatically mean that the result of the operation is satisfactory in all respects Nor does absence of synostosis mean that the treatment was a failure (Table 4) 2 feet improved decisively and 1 foot was fully satisfactory after treatment although there was no synostosis formation The functional result of the slightly under corrected feet was very good while 2 of the 4 over corrected feet showed symptoms owing to the varus position even if this was moderate This point is in agreement with general experience that the valgus position is much less productive of symptoms than varus During the operation it is necessary to overcorrect the malposition between the calcaneus and talus when the transplants are to be positioned but when these are in place the heel should take up a O position or slight valgus In all the 4 cases with overcorrection this was recognized at the conclusion of the operation and the foot was encased in plaster in this position which was later to emerge as permanent Thus we can draw the conclusion that under no circumstances out of fear of valgus recurrence must we be led into approving a varus position

TABLE 4

Results of Extra Articular Subtalar Arthrodesis in Flat Feet

	No of feet
Osseous ankylosis calcaneus talus achieved with both in a normal position in relation to each other The result is optimal both functionally and cosmetically	21
Osseous ankylosis achieved but with the valgus position insufficiently corrected Functionally a good result but cosmetically not quite satisfactory	3
Osseous ankylosis achieved but with a slightly overcorrected position with slight varus sequelae 2 in this group have slight discomfort in jumping and with greater exertions Wedge osteotomy on the calcaneus is contemplated 2 are quite symptom free	4
Osseous ankylosis not achieved but the condition improved both functionally and cosmetically Used arched soles	2
Osseous ankylosis not achieved and the condition remains the same as before the operation both functionally and cosmetically	6
Osseous ankylosis not achieved but the calcaneus and the talus maintained a normal position after operation Subjectively and objectively the patient is symptom free Good mobility in the subtalar joints	1
Total No of feet operated on	37

At the follow up examination particular care was taken to bring to light possible subsidiary effects of the operative treatment such as

1. growth disturbances in the affected bones
2. functional disturbances as a result of the lack of mobility in the subtalar joints and
3. possible changes as a result of this in the talo crural and Chopart's joint

In my opinion I found definite growth disturbance in one case. Compared with the non operated foot the talus was obviously of lesser size and the trochlea was flattened. X-rays taken before the operation do not shows this. The patient had no subjective symptoms.

The passive and active mobility in the talo crural and Chopart's joint was not found to be reduced in any case when compared with the pre operative period. Nor could any instability in the ankle joint be demonstrated. The patient's ability to balance on the operated foot was found throughout, however, to be somewhat reduced. The gliding lateral movement in the subtalar joints which serves to adjust the balance more finely was replaced by clumsier movements of the body. In other respects. In all cases with osseous ankylosis between calcaneus and talus the patient had the impression that the function of the foot was normal in respect to balance. The subjective evaluation of the patient must here be seen against the background of the condition of the foot before operation.

In the majority an inversion of the heel was recorded when the patient weightbearing with 4 cms underneath the heel but in no case was this so marked that it could be said to have a functional significance at the examination.

Signs of arthrosis in the talo crural or Chopart's joint were not revealed in any case.

DISCUSSION

The cases of flat feet in children treated here by extra articular subtalar arthrodesis according to *Grice* form a unique group. The material does not comprise typical cases of congenital flat feet nor cases with recognized pareses of the tibial musculature or peroneal spasm. In all cases the deformity was severe and showed no signs of improvement in spite of lengthy active dynamic and static treatment. We must conclude that these patients would have incurred without operative treatment a permanent foot deformity with increasing structural changes in the bones, capsules and ligaments.

It must be now considered as an established fact that the extra articular arthrodesis affects the growth of the bones concerned to a very little extent. Where the result of the operation is a solid bone bridge between calcaneus and talus and these are in a normal position there are grounds for considering the treatment as completed and that no later articular arthrodesis will become necessary.

The series shows that the expectation of achieving a solid extra articular arthrodesis will decrease to some extent with any increase in structural changes and that this may indicate modifications of the original surgical method.

Bone transplants must be selected with care. Grice's method using 2 bone blocks each consisting of cortical and cancellous bone placed parallel with the cancellous aspects facing each other should not be departed from. When these conditions are satisfied this series does not provide any grounds for assuming that we can achieve better results *with auto than with homotransplants. Moreover there is the consider*able advantage in using homotransplants that an osteotomy on the upper part of the tibia is avoided. If however the bone bank does not contain fully suitable material there should be no hesitation in utilizing autotransplants.

By means of the extra articular arthrodesis we succeed in improving the function of a foot with severe flat foot position but the function does not become normal. What significance this altered function in the long run will prove to have for the talo crural and Chopart's joint is still an open question. This makes a critical indication position particularly justified in the case of flat feet.

SUMMARY

A series of 37 flat feet treated with extra articular subtalar arthrodesis according to *Grice* were followed up.

In each case the operative indication was a pronounced foot deformity with functional symptoms and showing no sign of improvement after active dynamic and static treatment.

After an average observation period of 4 years the results of the surgical treatment were satisfactory in 78 per cent. The causes of unsatisfactory results in the remainder are clarified.

As far as extra articular subtalar arthrodesis is concerned the necessity *of a critical indication position with the simple* flat foot deformity is emphasized.

RESUME

Une serie de 37 pieds plats traites par arthrodese subtalaire extra articulaire selon la methode de Grice a ete reexaminee

Dans chaque cas l indication de l intervention chirurgicale avait ete une deformite prononcee du pied avec symptomes fonctionnels dans lesquels on n avait pas observe d amelioration apres traitement actif dynamique et statique

Avec une periode moyenne d observation de 4 ans les resultats du traitement chirurgical ont ete satisfaisants dans 78 pour cent des cas Les causes de resultats non satisfaisans chez le reste des malades ont ete clarifiees

En ce qui concerne l arthrodese subtalaire extra articulaire il est insiste sur la necessite d une indication critique de position par rapport a la deformite du simple pied plat

ZUSAMMENFASSUNG

Eine Reihenfolge von 37 Plattfussen die mittels extraartikulärer subtalarer Arthrodese nach der Methode von Grice behandelt worden waren wurde nachuntersucht

In jedem Falle war die Operationsanzeige eine ausgesprochene Fuss verbildung mit funktionellen Symptomen und keinerlei Zeichen von Verbesserung nach aktiver statischer und dynamischer Behandlung

Nach einem durchschnittlichen Zeitraum von 4 Jahren waren die Ergebnisse der chirurgischen Behandlung in 78 Prozent zufriedenstellend Die Ursachen der unbefriedigen Ergebnisse bei den Übrigen werden klargelegt

Was die extra artikuläre subtalare Arthrodese anbelangt wird die Notwendigkeit einer kritischen Stellungsnahme bei der Indikation in Fällen von einfacher Plattfussverbildung hervorgehoben

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METHOD OF STABILIZING AUTOPSY SPECIMENS IN BIOMECHANICAL EXPERIMENTS

By

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In reproducing trauma acting on major parts of fresh autopsies one of the experimental problems to be overcome is the method of fixing the specimens in the desired positions. So far, the skeletal parts have been anchored mostly in vices, although sometimes the bone ends have been nailed, screwed to metal plates, or fixed in special devices built in or close to the compression machines.

The stability obtained by the above methods was usually insufficient due to the fact that cortical bone does not withstand such fixations: it breaks or becomes loose, and cancellous bone does not give enough support: it softens and gives away.

To obtain improved stability we have tried several imbedding procedures, i.e. low fusion point metals, plaster of Paris, plastic materials and unfilled polyester resins. None of these materials, however, proved satisfactory, either because of long setting times, insufficient adhesion to the specimen due to its moisture content, or inability of the material itself to withstand the forces applied. All these difficulties prevented us from studying different types of mechanical forces to the extent we want. The complexity of questions in analyses of the spine and the joints in regard to traumatic lesions where forces have to act from different directions could not be experimentally approached. Since we are very fortunate in getting fresh cadaveric material for biomechanical purposes, we were prevented from exploiting our facilities. An adequate method of fixation would open up a wider field for experimental work.

More than a year ago we were fortunate in finding what we feel to be the best method tried so far. This involves using a polyester based mastic intended mainly for the repair of automobile bodies and for filling and jointing purposes both domestically and industrially. It

consists of two components a liquid and a powder The liquid is a modified polyester resin containing accelerator The powder consists of chemically inert fillers which enhance the mechanical properties of the polyester and also contains a peroxide catalyst which causes a mixture of the two components to set to a hard mass as a result of the polymerization of the polyester

The setting time depends on two factors firstly the fixing ratio of the components the more powder i e peroxide used the faster the setting time A thick paste will give a setting time of about 8 minutes while a thin paste such as might be used to fill cavities or very uneven surfaces will take up to 15 minutes to set at room temperature Temperature is the second factor involved The polymerization of polyesters is retarded at temperatures below 15 C and considerably accelerated as the ambient temperature increases

The polymerization reaction that occurs is exothermic and the temperature attained by the setting mastic depends on the bulk being used but does in our experiments not exceed handling limits or affect the bone ends

The mastic used by us can be moulded to any shape or form and shortly after setting can be machined or drilled as desired

In practice the bone ends of fresh cadaveric material are left for about ten minutes in a mixture of acetone and ether to remove the moisture on the outer surfaces and after drying for a few minutes placed in the freshly mixed mastic in the mould and then left undisturbed until the setting time is over

The moulds used are cube shaped and have been specially machined to fit our testing devices and in order to use them many times certain preparatory procedures have to be followed to permit release of the mastic from the mould at the conclusion of the experiment

The mould surface must be absolutely clean and free from traces of hard mastic Washing with ethyl acetate is usually sufficient The mould must now be treated with a release agent which can take the form of wax lecithin petroleum jelly mixtures silicone solutions or even thin sheets of polythene or cellulose In our work a thin layer of wax is applied to the inner surface of the cleaned mould followed by a brushed coating of silicone solution To facilitate easy removal of the mastic from the mould two holes have been drilled in the bottom to allow pressure to be applied to the set mastic itself For the very best release from the mould the surfaces should be highly polished and as free from surface imperfections as possible The mastic used here has

been formulated to have the best possible adhesion to metal surfaces for its normal use and great care must therefore be taken over the application of the release agent.

The mastic has not interfered in any way with the experiments, the amount of material to hold the specimens is very small. Lesions in the "holding area" do not seem to occur since the distribution of forces at the point of fixing is spread over an area that can be adjusted with regard to the forces involved in the experiment. In the study of fracture mechanism in some experiments more than a thousand kilograms are used. The anchoring of the specimens has been sufficient even when bending and torque has been applied.

In evaluating bony operating procedures such as arthrodeses, osteotomies and spinal fusions it is highly desirable to perform autopsy experiments in order to test the mechanical response to various methods. So far it has only been possible to check osteosyntetic devices with regard to immediate stability. To get fused specimens for biomechanical analysis is rarely possible unless one starts animal work. Again then the premises are completely different.

The mastic we have used can be adopted as a bone glue which may to some extent simulate callus. Bone grafts can be applied, osteotomy surfaces can be jointed and different types of arthrodeses performed in backs and joints in autopsy material and tested with respect to mechanical efficiency.

SUMMARY

Different stabilizing procedures in biomechanical experiments in autopsy material have been studied. The purpose is to fix bone ends of joints and spines in order to apply different types of forces until fractures or other lesions occur in order to analyse the underlying mechanism of traumatic lesions. The aim has also been to study the mechanical efficiency of spinal fusions, arthrodeses and osteotomies with regard to different techniques.

The best method tried so far for fresh autopsy bones has been a mastic consisting of two components, a liquid of a modified polyester resin containing accelerator to be mixed with powder of a chemically inert filler which enhances the mechanical properties of the polyester and also contains a peroxide catalyst which causes a mixture of the two components to set to a hard mass. This is the result of the polymerization of the polyester.

The application is discussed and technical experiences presented. It

is strongly felt that this method of fixation opens up a wider field for laboratory experimentel orthopaedics from which clinical knowledge can be obtained

RESUME

Differents procedes de stabilisation ont ete examines au cours d'experiences biomecaniques de materiel d'autopsie. Le but etait de fixer les extremites des os dans les articulations et la colonne vertebrale afin d'appliquer differents types de forces jusqu'a ce qu'il se produise une fracture ou d'autres lesions pour pouvoir analyser le mecanisme determinant des lesions traumatiques. On avait en outre aussi l'intention d'etudier l'efficacite mecanique des fusions vertebrales, des arthrodèses et des osteotomies en ce qui concerne differentes techniques.

La meilleure methode essayee jusqu'ici pour les os d'autopsie fraiches a ete un mastic forme de deux composants: un liquide d'une resine polyester modifiee contenant un accelerateur a melanger a une poudre de remplissage chimique inerte rehaussant les proprietes mecaniques du polyester et contenant aussi un peroxyde catalyseur qui produit le melange des deux composants de maniere a former une masse dure. C'est le resultat de la polymerisation du polyester.

Cette application est discutée et des experiences techniques sont presentees. On a bien l'impression que cette methode de fixation ouvre un large champ auf experiences orthopediques de laboratoire *d'ou des* connaissances cliniques pourrent etre tirees.

ZUSAMMENFASSUNG

Verschiedene stabilisierende Verfahren wurden in biomechanischen Versuchen an einem Autopsiematerial untersucht. Es war die Absicht Knochenenden von Gelenken und Wirbelsäulen zu fixieren und verschiedene Kraftarten zu verwenden bis Bruche oder andere Beschadigungen auftraten um den zugrunde liegenden Mechanismus traumatischer Schädigungen zu analysieren. Die Absicht war es auch die *mechanische Leistungsfahigkeit* von Wirbelverschmelzungen, Arthrodesen und Osteotomien unter Berucksichtigung verschiedener Techniken zu studieren.

Die best bisher an frischen Autopsieknochen versuchte Methode ist eine Mastixlosung, die aus zwei Komponenten besteht: einer Flussigkeit eines modifizierten Polyesterharzes, das einen Accelerator enthalt und mit dem Pulver eines chemisch inaktiven Fullstoffes gemacht

wird der die mechanischen Eigenschaften des Polyesters steigert und auch einen Peroxid katalysator enthalt welcher bewirkt dass die Mischung beider Komponenten eine harte Masse ergiebt Dies ist das Ergebnis der Polymerisierung des Polyesters

Die Anwendung wird besprochen und technische Erfahrungen werden gegeben Man ist uberzeugt dass diese Fixierungsmethode ein weites Feld für die experimentelle Laboratoriumsorthopedie eroffnet von der klinische Erkenntnis erhalten werden kann

ACKNOWLEDGMENT

The mastic we have used is sold in Sweden under the name of Plastic Padding It can naturally only be used in cadaveric experiments

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